Effects of a Curriculum-Based Intervention on the Increments of Stimulus Control for Bidirectional Naming and Student Learning

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Abstract

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In two experiments, I tested the effects of a curriculum-based intervention on preschool students' degree of stimulus control for bidirectional naming (BiN) across familiar and unfamiliar word-picture relation levels of complexity. In Experiment I, I used a multiple probe design to test the effects of the curriculum-based intervention on the degree of BiN for familiar word-picture relations. All four participants in the first experiment demonstrated an increase in the degree of BiN for familiar picture-word relation, with three participants meeting the incidental BiN criterion level of 80% across three response topographies. In Experiment II, I compared the curriculum-based intervention and repeated novel naming experience (RNNE) on preschool students' degree of BiN and learning. The dependent variables were 1) degree of stimulus control for BiN across familiar and unfamiliar word-picture relations 2) learn units to criterion across math and reading 3) percentage of correct responses to unconsequated post-math and reading instruction probes. I investigated whether the method of acquisition of BiN, a curriculum based or RNNE, has differential effects on the dependent variables. Three out of four participants who received the curriculum-based intervention acquired BiN for picture-word relations following a novel experience, while one out of four participants under the RNNE condition acquired BiN. The results of the study suggest that a curriculum-based instruction can simultaneously induce BiN while teaching academic objectives to preschool students. Experiment II also implicates the effects of a technology-mediated intervention on developing academic and verbal behavior development cusps even in young children.

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Dedication

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CHAPTER I:

INTRODUCTION AND REVIEW OF THE LITERATURE

I compared two interventions with preschoolers, a repeated novel naming experiences (RNNE) versus an academic curriculum-based intervention on inducing demonstration of bidirectional naming for incidental learning of language across two levels of complexity (i.e., familiar picture-word relation, unfamiliar picture-word relation) in preschool students. Other dependent variables were the rate of learning (i.e., number of learn units to criterion) across reading and math objectives and participants' correct responses to unconsequated post-instruction unit tests.

The review of literature addresses the academic needs of students in the United States and the effects of early childhood curricula widely used across the country. I will also address the interaction between these curricula and language acquisition with the importance of language acquisition in early childhood for children's academic success in upper grades. Additionally, I will discuss language acquisition from related research in non-behavioral psychology and verbal development. I discuss the verbal behavior development theory, which identified verbal behavior cusps and research-based interventions to induce those cusps if missing in children's repertoires. The verbal behavior development theorists focus on the effects of bidirectional naming (BiN) and interventions that effectively induce this verbal development cusp, rather than the effects of BiN on mutual or combinatorial entailment (i.e., relational frame theory). Finally, I present the rationale for the current study to address the missing components in previous research on children's academic content and language acquisition.

Academic Deficits and Needs

Students in the United States versus the World

Despite the economic advantages and numerous curricula, students in the United States continue to perform poorly in mathematics and reading than in other developed countries. The results from the 2018 *Programme for International Student Assessment* (PISA) revealed alarming facts about where American students currently stand in reading and mathematics achievement. PISA is a worldwide student assessment conducted by the *Organisation for Economic Cooperation and Development* (OECD) to evaluate education systems by testing 15-year-old students' reading, mathematics, and science performance. According to PISA, the United States students performed below the OECD average, placing at 34th in math and slightly above the average, placing at 12th, in reading among 79 countries. The poor performance of our students is highly distressing especially considering the economic advantages of our students. According to the OECD gross domestic product per capita (GDP), which reflects a country's economic productivity, the United States is in fifth place among the OECD countries (OECD, 2018). The discrepancy between the United States' economic productivity and students' poor academic performance raises a critical issue in America's education. What can we do to prevent academic failures at the age of 15? The answer may lie in implementing appropriate early childhood education to set the students up for long-term academic success.

Early Childhood Education and its Effects

The importance and the long-term positive effects of a quality early childhood education are widely recognized. In a recent longitudinal study, Bai and colleagues (2020) investigated the differences between middle school students in North Carolina who received "quality" state-funded preschools and the students who did not receive any preschool education. They surveyed approximately 90,000 students in each middle school grade (i.e., grades 6, 7, 8). They found that the students who received early childhood education had higher end-of-the-year reading and math scores, were less likely to receive special education, and were less likely to be retained in a grade. These results showed that a quality early childhood education has a long-term effect on students' academic performance.

In another study, Temple and Reynolds (2007) studied the cost-effectiveness of receiving a quality early childhood education across three different quality preschool programs in the United States. The researchers revisited the graduates of these programs 17 to 25 years later. The students who graduated from preschool programs had lower rates of special education services, reduced grade retention, and higher college attendance rates than their peers who did not receive quality preschool education. According to their cost-benefit analysis, they determined that high-quality preschools have high rates of positive economic returns. If it is clear that early childhood education produces long-term academic benefits, what are some components that preschools provide to young children?

Language and Early Childhood Education

Most early childhood curricula have strong emphases on children's language development. In 2003, Shaul and colleagues reported the effects of Head Start preschool programs predominantly using Creative Curriculum® (Dodge et al., 2002) and High/Scope® (High/Scope, 1989) based on teacher interview data reported using Family and Child Experiences Survey (FACES), a longitudinal survey. The teachers interviewed reported that most children experienced language-based activities, such as listening to stories and discussing new words, to promote language and cognitive development daily. However, there were no numerical data to support teachers' reports on promoting children's language development using these curricula.

High/Scope (High/Scope, 1989) implements an "active learning" approach in their curriculum (High/Scope, 2020). They claim that the active learning approach promotes children's creativity, confidence, and school readiness. According to High/Scope, the five ingredients of active learning are materials, manipulation, choice, child language, and adult scaffolding. Within their curriculum, they encourage the teachers to implement various strategies to promote language development. Lockhart (2012) suggested implementing three key ingredients of the High/Scope curriculum: communication in a trusting relationship, learning through doing, and a vocabulary-rich environment.

Creative Curriculum (Dodge et al., 2012) also emphasizes language development in preschool children in their curriculum. They suggest providing language opportunities, supplying language to assist children, and facilitating the oral language in play (Teaching Strategies, 2010). The most recently updated edition, Creative Curriculum, emphasizes the function and use of language in children. They suggest implementing materials that promote language development while using the curriculum (Teacher Strategies, 2010).

These widely used and commercially available curricula for preschool children recognize the importance of early language development. Next, I will discuss the importance of language development in the early years and its relations to later academic achievements.

Early Language and Academic Achievements

The famous study by Hart and Risley (1995) points us in the right direction of where we can start. They recruited 42 families of various backgrounds. They suggested the term "thirty-million-word gap" to indicate the gap between toddlers from low socio-economic-status families and those from high socio-economic status families. They found that these two groups of toddlers have approximately a gap of thirty million words in exposure in the first two years of their lives. Hart and Risley also found a significant correlation between word exposure and the rate of language acquisition in toddlers. Furthermore, they followed up with 29 families to test children's language and academic skills at nine and ten years of age. They found that vocabulary growth (i.e., rate of language acquisition) was strongly associated with their language skills even after six to seven years of interfering experiences.

More recently, Duncan and colleagues (2007) analyzed six longitudinal data sets to identify school readiness skills that are most relevant to later academic success. They identified reading, language ability, math, attention, socioemotional behaviors, and social skills as school readiness skills. Among these skills, they found that reading/language, math, and attention were the only skills that significantly predicted later academic success. Additionally, they found that early math and language skills were the most powerful predictors of students' later academic achievements. Language development in early childhood is vital in setting children up for academic success in later years. In the following section, I will discuss various theories of language acquisition.

Language Acquisition

Developmental and Cognitive Psychology Approach to Language Acquisition

Language is one of the most complex human behaviors. Rightfully so, many psychologists, philosophers, linguists, and other scholars continue their studies to answer the question of language acquisition. The developmental psychological point of view on language acquisition emphasizes the importance of social interaction and experiences. Developmental psychologists suggested multiple theories of language acquisition: Vygotsky's (1978) sociocultural theory, Bruner's (1981) interactionist theory, Gardner's (1983) multiple intelligence theory, and Tomasello's (2003) socio-pragmatic usage-based theory.

Interactionist Theory. Interactionist linguist theory from developmental psychology argues that language acquisition occurs through multiple sources: world knowledge, maturation, and social relationships. Bruner (1981) suggested that world knowledge plays the strongest role in language acquisition. According to Bruner, world knowledge is the cognitive structure (i.e., schema) developed by the learner based on past and current knowledge (Bruner, 1983). The world knowledge facilitates linguistic learning. That is, the addition of a linguistic label to an object that already exists in a child's world knowledge will be easier than if the child did not have the conceptual knowledge. Social relationships serve as a clue for language acquisition (Bruner, 1982). The social relationship critical to language development, according to interactionists, is the relation between the child and a mature adult who can serve as a model of language and provide appropriate language input to the child.

According to Vygotsky, providing scaffolds within the child's zone of proximal development (Vygotsky, 1978) will benefit the child's language development. Zone of proximal development refers to the continuum in which a child could learn without guidance and in need of guidance from others. In this process, scaffolding occurs, which refers to providing appropriate support to children in the zone of proximal development for them to reach their goals (Vygotsky, 1978). The pragmatic language develops due to the child's "commitment to social interaction" (Bruner, 1982, p.7). While the format of the social interaction begins as an infant between a mother and the infant, the child acquires language as the social interaction format expands beyond the mother-child relations.

Socio-Pragmatic or Usage-Based Theory. According to Tomasello (2003), fundamental skills of joint attention and cultural learning allow children to acquire adequate cognitive skills to form language acquisition processes. Usage-based theory of language acquisition, proposed by Tomasello (2003), derives the process of language acquisition by summarizing two aphorisms suggested by linguistic philosophers Wittgenstein and Langacker. The first aphorism, "meaning is use," leads to Tomasello's intention-reading, which is a process in which a child comprehends the goals of a speaker to attain a social goal. Intention-reading focuses on the function of communication which is meeting the social ends of the individuals involved in communication (Tomasello, 2008). The notion of intention reading also supports the social pragmatic approach to language acquisition (Bruner, 1983) that focuses on joint attention as a prerequisite for communication. Communication between humans can only take its effect when the humans share a common conceptual ground. The second aphorism in the usage-based theory is pattern-finding. Pattern-finding focuses on the schema and construction of languages, such as grammar and syntax. He argues that children comprehend multiple utterances of language and then extract smaller utterances that have functions and find analogical patterns of the utterances. This process allows children to learn grammatical constructions and language schema.

Behavioral Analytic Approach to Language Acquisition

Behavior scientists have contributed a great deal to the study of language acquisition, starting from Skinner's (1957) theory of verbal behavior. Expanding on verbal behavior (Skinner, 1957), behaviorists continued to study complex human behavior of language by establishing theories that explain the emergent relations in language.

Verbal Behavior. Skinner (1957) defined verbal behavior in his theoretical account of the function of language as the listener's behavior mediates the speaker's reinforcement. Skinner distinguished verbal behavior from language. Verbal behavior focuses on the function as the speaker's verbal behavior is reinforced by the verbal community (i.e., referred to socio-pragmatists as usage-based of intention). Conversely, linguists focus on the form (i.e., schema, according to socio-pragmatic linguists), thus not explaining humans' verbal behavior (Donahoe & Palmer, 2004). Skinner (1957) suggested the appropriate unit of analysis of the communicative function of language was the verbal operants he defined based on the speaker's verbal operant function.

The verbal operants identified by Skinner (1957) are mand, echoic, textual, intraverbal, tact, and transcription operants. When a speaker emits a mand, the response mediated by the listener specifies the reinforcement without an antecedent stimulus. Echoic, textual, and intraverbal behaviors occur in the presence of a verbal antecedent, while generalized reinforcers control the behavior. A tact is emitted under a nonverbal antecedent stimulus and controlled by generalized reinforcers. Additionally, Skinner (1957) also theorized the bidirectionality of the listener and speaker behavior using the term speaker-as-own-listener while specifying that the listener and speaker were developmentally independent. However, he inferred that listener and speaker behaviors join as children learn from contacts with their verbal community. Skinner's study of verbal behavior continued to expand as described in the following.

Stimulus Equivalence. Sidman (1971) introduced the notion of stimulus equivalence in his seminal study as he investigated the auditory and visual equivalence in reading. Sidman found that when he taught the hearing-matching printed word relation to a student who had already learned seeing picture-saying word relation, the relation between seeing word-matching picture emerged without direct instruction (Sidman, 1971). Sidman suggested that stimulus equivalence is a critical prerequisite for reading comprehension. Additionally, he recommended using equivalent classes to facilitate faster language acquisition.

Stimulus equivalence is a hierarchical and bidirectional relationship between stimuli, allowing these stimuli to be interchangeable with one another (Tailby & Sidman, 1982). This phenomenon occurs when three or more stimuli are functionally interchangeable. There are three components in the stimulus equivalence theory: reflexivity, symmetry, transitivity. Reflexivity is the relation with its stimulus, represented as A=A. One demonstrates reflexivity when shown an apple and can later determine that it is identical to the last apple. Symmetry is the bidirectional relation with another stimulus, represented as A=B then B=A. One demonstrates symmetry when taught that a visual stimulus dog is the same as the auditory stimulus "dog" and can form the relation of auditory to the visual stimulus of a dog. Transitivity is the emergent relation when three or more stimuli in symmetrical relations are combined, represented as A=B, B=C, then A=C. Transitivity is demonstrated when one learns that a visual stimulus of milk is the same as the written text "milk," while the written text "milk" is the same as the auditory stimulus "milk." The relation between visual and vocal stimulus milk emerges without direct instruction. Though stimulus equivalence presents minimal empirical results on language development, the theoretical implications suggest one can acquire language through relations proposed by the stimulus equivalence theory.

Relational Frame Theory. Relational frame theory (RFT) is an extension of stimulus equivalence theory to explain other complex human behaviors, such as language and cognition, that could not be explained using Sidman's stimulus equivalence and Skinner's verbal behavior (Hayes, 1994). RFT's core unit of analysis is arbitrary applicable relational responding (AARR; Hayes et al., 2001), derived relational responding based on contextual cues. These relations are mutual entailment, combinatorial entailment, and transformation of function. Mutual entailment is a bidirectional relation between two stimuli (e.g., A<B then B>A). For example, one demonstrates mutual entailment when given "Mark is taller than Sam," then produces "Sam is shorter than Mark." Combinatorial entailment is the relation among mutual entailment relations mutually combined (e.g., A<B=C then A<C, C>A). One demonstrates combinatorial entailment when given "Mark is taller than Sam. Mark and Jack are the same height," produces "Jack is taller than Sam" and "Sam is shorter than Jack" without directly being taught. Transformation of stimulus function is when a relation acquires the function of another relationship as a result of derived relational responding. Transformation of stimulus function is demonstrated when Sue has two candies as reinforcers, M&M™s and Skittles™, while she prefers M&Ms (i.e., A>B). When a paper clip and skittles are paired, and the paper clip acquires the same strength as a reinforcer (B=C), the paper clip will function as a reinforcer but have weaker reinforcer strength in comparison to M&Ms (A>B=C). The function of Skittles transferred to paper clip as well the relation established between M&Ms and Skittles prior to paper clip entering the relations.

RFT proposed that incidental language acquisition occurs between stimuli through environmental relations and contexts (Barnes-Holmes et al., 2000). When multiple exemplar training established derived relational responding among stimuli, novel frames of relations emerged within specific contextual cues, resulting in the acquisition of language frames and environment-language relations that was not a part of one's repertoires before the training. Empirical findings suggest multiple exemplar training (MET) can establish relational frame theory. Barnes-Holmes and colleagues (Barnes-Holmes et al., 2001) taught perspective-taking skills to students with developmental disabilities using MET. Additionally, researchers taught opposition frames of various pronouns (e.g., he, she, we, I, you, him, her, etc.) using discrimination of relation training (Barnes-Holmes, et al., 2005). Following the intervention, the students demonstrated perspective-taking of untaught relations. Additionally, students with and without disabilities learned the frame of coordination (Berens & Hayes, 2006) and comparative (Murphy & Barnes-Holmes, 2004) using MET.

In summary, relational frame theorists argue that relational responding provides explanations for language development from a behavioral perspective by tracing the relations within the environmental context. As demonstrated in previous research (Barnes-Holmes et al., 2004; Berens & Hayes, 2007; Murphy & Barnes-Holmes, 2009), MET can effectively teach language. In MET, the untaught relations emerge across stimuli based on the contextual cue in the environment and history or arbitrary applicable relational responding.

Naming Theory. Naming is a higher-order bidirectional relation that allows an individual to access higher level and complex verbal behavior (Horne & Lowe, 1996). The notion of naming stems from Skinner's (1957) speaker-as-own-listener behavior. Naming repertoire emerges from the interaction between echoic, listener, and tact relations that a child experiences through the interaction with his caregiver. While listener and tact behaviors are unidirectional, naming behavior is bidirectional. In naming, the listener and speaker functions combine for either function to presuppose the other (Horne & Lowe, 1996). When naming is established, a child can learn to hear the word "apple" in the presence of an apple and learn the word "apple" as a speaker without reinforcement for this behavior. Therefore, when naming is present in a child's repertoires, they learn language incidentally in the environment as they contact stimuli as a listener.

Miguel (2016) reaffirmed Horne and Lowe's usage of the term "bidirectional" (Horne & Lowe, 1996) to distinguish naming behavior as mentioned above from other terms synonymous to naming, such as tacting and labeling. More importantly, Miguel (2016) suggested terms that further classify bidirectional behaviors that involve learning visual and vocal stimuli relations. Bidirectional naming (BiN) refers to the naming initially presented by Horne and Lowe (1996). Common bidirectional naming (C-BiN) explains equivalent class formation when one learns the relation in both functions of listener and speaker. Intraverbal bidirectional naming (I-BiN) refers to the intraverbally linked stimuli relations. Lastly, joint control (JC), a suggested addition by Miguel, explains the establishment of stimulus control for a single response topography when two stimuli are presented simultaneously.

More recently, Hawkins et al. (2018) proposed a further classification of C-BiN (Miguel, 2016) depending on whether the target names of stimuli were taught or emerged without direct teaching in any topography. Incidental bidirectional naming (i-BiN) is acquiring untaught listener and speaker behavior with exposures to names of stimuli without explicit instruction. Greer and Ross (2008) first introduced the notion of i-BiN as *full naming.* Within i-BiN, there are three subtypes: listener incidental unidirectional naming, speaker incidental unidirectional naming, and joint incidental bidirectional naming (Hawkins, et al., 2018, p. 52). When a child demonstrates incidental unidirectional naming as a listener or speaker, he can use the novel names as a listener (e.g., select target stimulus) or as a speaker (e.g., tact target stimulus), respectively, in isolation. When a child demonstrates joint incidental bidirectional naming (i-BiN), he acquires the names of stimuli as both listener and speaker functions without direct instruction (see Figure 1). Throughout the rest of this paper, I will use i-BiN interchangeably with BiN as the target of current studies are in correspondence with children's incidental language acquisition.

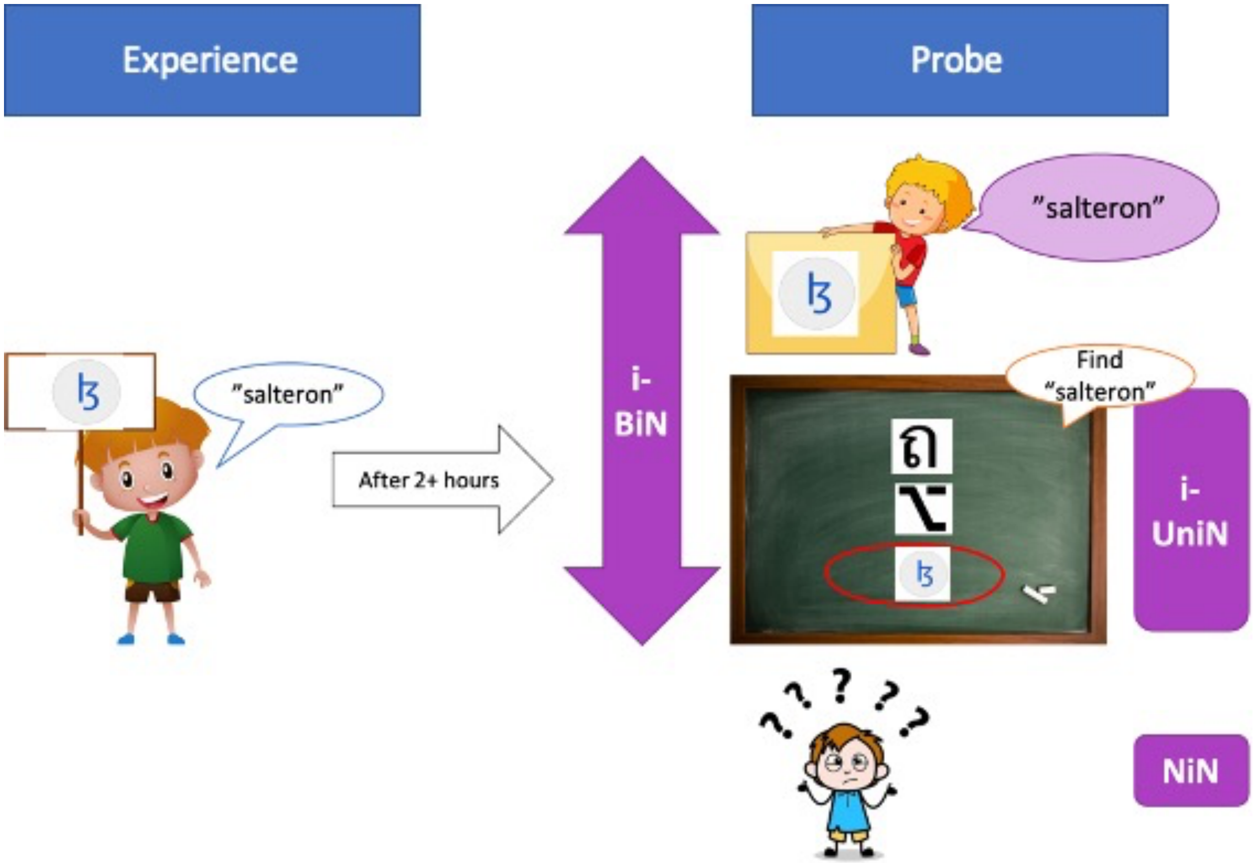


Figure 1. A visual representation of demonstration of subtypes of incidental untaught bi-directional naming (i-BiN).

Horne and Lowe (1996) suggested naming can be established by training the components that lead to the emergence of naming in a natural environment: echoic, listener, and tact behaviors. Empirical findings suggest that training involving rotation of listener and speaker topographies of behavior lead to the emergence of i-BiN (Fiorile & Greer, 2007; Gilic & Greer, 2011; Greer et al., 2007; Greer et al., 2005). Acquiring i-BiN is a critical developmental milestone that leads to an exponential expansion of language from incidental observation (Greer & Longano, 2010). While children who do not present i-BiN need reinforcement for all topographies of verbal behavior, children who demonstrate i-BiN acquire language incidentally in the environment through experience (Hawkins et al., 2018).

Based on decades of research across psychology, linguistics, and philosophy, the scholars seem to agree that language acquisition is an important topic of study. Additionally, we know that young children who have a faster rate of language acquisition and a strong language foundation are more likely to succeed academically in the future. The verbal behavior development theorists suggest that children learn language at a different rate or in different ways depending on the presence of certain verbal behavior development cusps. Additionally, they found that these verbal behavior development cusps can be induced using specific protocols.

Verbal Behavior Development Theory (VBDT)

The verbal behavior development theory (VBDT), constructed on Skinner's theories (Skinner, 1957) and a program of research for over three decades, identifies verbal behavior developmental cusps and capabilities. The VBDT identified developmental cusps that allow one to learn previously inaccessible repertoires, allowing an individual to communicate and contact social contingencies with others and learn using different types of instruction (Greer et al., 2017). Over three decades of research in verbal behavior development focused on how one can acquire verbal behavior cusps and the implications of these cusps related to learning to maximize the effects of instruction.

According to Baer and Rosales-Ruiz (1998), behavioral cusps change how a person interacts with the environment. Therefore, it enables multiple interactions that were not possible prior to the acquisition of the cusp. When new interactions are made possible by establishing a cusp, one can learn in ways one could not before or accelerate the rate of learning (Greer & Ross, 2008). A succession of verbal behavior cusps is identified that establishes appropriate stimulus control following developmental milestones from observing responses as infants, listener, speaker, joining of the listener and speaker behavior, and extensions of verbal behavior to reading and writing (Greer et al., 2017). In addition to verbal behavior cusps which allow for new person-environment interactions, a verbal behavior cusp that is also a learning capability establishes the ability to acquire new operants via a means that was inaccessible to the learner (Greer & Ross, 2008). For example, when a student acquires the verbal behavior capability of gross motor imitation, the student can now learn by observing other's model whereas, previously, the student needed direct physical prompts due to the lack of seeing and doing correspondence (Du & Greer, 2014). VBDT not only identified verbal behavior cusps and capabilities but also developed protocol interventions for students missing these cusps (Greer & Speckman, 2009).

Preverbal Foundations

According to VBDT, if a child does not have preverbal foundation cusps in repertoires, he is entirely dependent on others. He lacks the necessary prerequisites to allow him to interact with the environment and the social community. These foundational verbal development cusps start developing in utero as the fetus's nutritional input pairs with the mother's voices. The development continues immediately after birth to establish multiple conditioned reinforcers, such as conditioned reinforcement for observing faces and voices (Pohl et al., 2018).

Prior to acquiring conditioned reinforcement for observing 2D and 3D stimuli, the visual stimuli in the environment do not have an embedded reinforcer value to those children (Delgado et al., 2009). However, when children acquire this cusp, they can learn new operants presented in visual 2D or 3D stimuli, a critical prerequisite for listener and speaker verbal development. Conditioned reinforcement for observing faces and voices is a vital prerequisite to interact with the social community. When children have this developmental cusp in their repertoire, they will orient to humans' faces or voices, allowing children to interact with other members of the social community in a way they could not before (Maffei et al., 2014). Conditioned reinforcement for seeing and doing (i.e., generalized imitation) is a verbal developmental cusp that is also a learning capability. With this cusp in the repertoire, children can acquire new operants by imitating others, accelerating the rate of acquisition as the child can now learn by seeing instead of directly being taught (Greer & Keohane, 2005).

Listener and Speaker Cusps Prior to Joining

Listener developmental cusps allow children's behavior to be governed by speakers' verbal antecedents. Some critical listener developmental cusps are auditory matching, listener literacy, conditioned reinforcement for listening to story content, and unidirectional naming (UniN). Auditory matching, or advanced phonemic awareness, allows one to discriminate auditory stimuli and identify positive exemplars that match the target auditory stimulus. Children also demonstrated improved echoics and an increase in the reinforcement value for voices following the acquisition of auditory matching (Choi et al., 2015; Greer et al., 2017). Listener literacy allows a child to follow vocal directions from a speaker (Greer et al., 2005). The emergence of listener literacy indicates a shift in stimulus control from visual-only to visual and auditory stimuli, establishing a new contingency between the child and the environment.

To acquire language incidentally in the bidirectional operant function, a child must learn language from antecedent stimuli in a unidirectional operant without receiving direct reinforcement to respond to the antecedent stimuli. A child will acquire the language as a listener prior to the joining of listener and speaker responses from experiencing language. Unidirectional naming (UniN), formerly the listener half of naming, is a verbal behavior cusp that allows a child to contact the pairing of visual and auditory stimuli and incidentally acquire the language as a listener (Greer & Ross, 2008).

When children acquire speaker verbal development cusps, they have greater contact with the environment and provide more opportunities to contact social reinforcers. As identified by VBDT, these speaker cusps are echoics, mands, tacts, and transformation of establishing operations across mands and tacts. Echoics, a prerequisite to all other speaker cusps, occur temporally adjacent to the verbal antecedent and have a point-to-point correspondence with the antecedent (Greer & Ross, 2008). When a speaker emits a mand, the listener's behavior is controlled according to the speaker's specified reinforcer. When children learn to mand, they can manipulate the environment as a speaker (Greer et al., 2006). While a mand specifies the target reinforcer, the target reinforcer of a tact is social reinforcement. With independent tacts in verbal development repertoires, children have a significant increase in social interaction opportunities with the verbal community (Schmelzkopf et al., 2017).

Those mentioned above verbal developmental cusps are prerequisites to the following bidirectional verbal cusps that allow one to become truly verbal (Greer & Ross, 2008).

Bidirectional Verbal Cusps: Joining of Listener and Speaker Verbal Developmental Cusps

The listener and speaker behaviors join when the stimulus control for listener behavior also control the speaker without directly being taught. Bidirectional operants can be demonstrated between individuals or within an individual.

Conversational Units. Conversational units are bidirectional operants between individuals. The conversational unit (Becker & Greer, 1988) is an expansion on Skinner's (1957) verbal episodes. A verbal episode is the composition of listener and speaker behaviors between individuals (Skinner, 1957). The individuals involved in verbal episodes assumed the role of and reinforced as both a listener and a speaker. Greer and Ross define conversational units as "social exchanges during which two individuals rotate both speaker and listener functions (Greer &

Ross, 2008, p.184). Each individual involved in a conversational unit responds in a three-term contingency (i.e., antecedent, behavior, consequence) of verbal behaviors (Donley & Greer, 1993). The chart below provides an example of a conversational unit between two individuals.

Self-Talk Conversational Units. The conversational unit can occur with oneself when an individual assumes the role of a listener and a speaker bidirectionally. Therefore, it is a bidirectional operant within an individual. Skinner described the overt vocal behavior that the speaker reacts as a listener to his own speaker behavior as the speaker serving as his own audience (Skinner, 1957). Self-talk is typically observed when children engage in fantasy play using toys. Lodhi and Greer (1989) found that children emitted self-talk units (i.e., overt conversational units with self) when presented with toys. Additionally, the number of self-talk units was higher in conditions where the children had anthropomorphic toys (e.g., puppets, stuffed animals) than nonanthropomorphic toys (e.g., puzzles, drawing material).

It is important to note that, even though one individual assumes both roles as a listener and a speaker, the function of the verbal behaviors must be identical to that of a conversational unit between two individuals. That is, the child engaged in self-talk must contact reinforcement both as a listener and a speaker. When children only assume the role of a speaker, the verbal behavior is unidirectional, distinguished from a self-talk conversational unit (Yoon, 2019).

Bidirectional Naming. Bidirectional naming (BiN) is also a bidirectional operant within an individual. BiN is a verbal development cusp that is also a new learning capability, allowing one to learn the names of things incidentally after the cusp is present (Greer, 2019). Children become fully verbal when they acquire BiN as they can learn language incidentally due to the shift in reinforcement from direct reinforcement to learned reinforcement (Greer et al., 2017). The learned reinforcement is the correspondence between the echoic hearing and saying. The selection of observing responses for the correspondence results from establishing a new stimulus control embedded in the experience allows one to learn the names of things incidentally. Due to the shift in stimulus control, the child can learn through antecedent stimuli rather than learning through reinforcement stimuli (Greer et al., 2017). As discussed above (Duncan et al., 2007), incidental language acquisition is a critical skill that predicts academic success. As the focus of the current study, BiN is further discussed in the following section.

Bidirectional Naming as a Dependent Variable

Levels of Complexity in Bidirectional Naming

Unidirectional Naming. Unidirectional naming (UniN) refers to when an individual only demonstrates the listener half of BiN. One may incidentally learn to respond as a listener (i.e., point-to, match) after hearing a word in the presence of a visual stimulus but cannot incidentally learn the speaker topography of the relation. According to the verbal behavior development research, UniN occurs developmentally before the child speaks and can learn before the child acquires a full speaker repertoire and serves as a critical prerequisite for acquiring BiN (Abdool-Ghany, 2020; Feliciano, 2006; Fiorile & Greer, 2007; Greer & Ross, 2008; Kleinert-Ventresca et al., 2021). When children demonstrate UniN, the rate of learning as a listener will accelerate in addition to a change in instructional delivery, but not as a speaker (Abdool-Ghany, 2020). Because children with UniN can incidentally learn listener topographies without direct instruction, they will only need direct instruction for speaker responses.

Bidirectional Naming for Familiar and Unfamiliar Stimuli. Most studies with BiN as a dependent variable used the picture and word relations to test the emergence of the untaught listener and speaker relations (Gilic & Greer, 2011; Greer et al., 2007; Greer et al., 2005). During the training experience of relations prior to the probe, the participants hear the auditory stimulus (i.e., word) while seeing or matching the corresponding visual stimulus (i.e., picture). A familiar stimulus refers to pictures or objects that children may contact in a natural environment, such as animals, flowers, and food (Greer et al., 2007). An unfamiliar stimulus refers to a visual and auditory stimulus that children are not likely to contact in a natural environment, such as logographic symbols or non-Latin-based language characters (Greer & Du, 2015).

Kleinert (2018) found a significant difference in correct responses to BiN probes depending on what type of stimuli used in the probe. Participants who demonstrated the presence of BiN when using familiar stimuli (e.g., flowers, bugs) did not show BiN when unfamiliar stimuli (e.g., arbitrary symbols) were used during the probe. Additionally, Morgan and colleagues found a significant positive correlation between children's degree of BiN for unfamiliar stimuli and the emergence of derived relations for arbitrary and non-arbitrary stimuli. However, the degree of BiN for familiar stimuli did not show differences (Morgan et al., 2020). Therefore, the findings from recent studies on BiN using familiar and unfamiliar stimuli suggest the distinction between degrees of BiN for familiar and unfamiliar stimuli as different levels of complexity.

Bidirectional Naming for Action and Word. Another level of complexity in BiN is the emergence of untaught relations between action and words. Cahill and Greer (2014) identified six types of responses that measure the dimensions of BiN after children experienced the pairings of vocal and action with and without objects. During the probes, they measured participants' responses to a selection of action, demonstration of action, joining of the action to vocal name, listener (e.g., hear name, point to object), tact, and intraverbal tact responses. The implications of their study suggest that one's history of reinforcement for observing responses select out which component stimuli one attends to. All participants emitted a higher percentage of correct responses across all listener probes than speaker probes, which replicated previous research findings. More importantly, all participants performed with higher accuracy in conditions where the stimuli were presented without action. This implies that the observing responses for action during experiences impeded incidentally learning of the names of the objects during the experience (Cahill & Greer, 2014).

Bidirectional Naming by Exclusion. Learning from exclusion is a procedure in which, when presented with previously known objects and an unknown object, the learner learns the unknown object by exclusion. Vincent-Smith et al. (1974) found that young toddlers learned the names of objects more quickly when taught using the exclusion procedure. Another level of complexity in BiN is BiN by exclusion. To test for the presence of BiN by exclusion as a cusp, Greer and Du (2015) conducted an exclusionary training as the incidental learning experience. The researchers presented an array of visual stimuli (i.e., four unknown, one known) to the participants. During the naming experience in both probes and interventions, the experimenter delivered the vocal antecedent of "Give me (name of unknown stimulus)." If the participant emitted a correct response, the experimenter delivered reinforcement. If the participant emitted an incorrect response (i.e., selected a non-exemplar to the vocal name), the experimenter did not provide a consequence. The experimenters tested whether the stimulus control for the untaught picture to object relations will emerge due to the process of elimination, derived from reinforcement or no consequence, during the exclusion training experience. Following the intervention with training sets, the participants acquired names from exclusions whereas, prior to the experiment, they only demonstrated basic naming, not naming by exclusion. The participants who showed BiN in a typical picture-word relation probe did not demonstrate BiN by exclusion

(Greer & Du, 2015), suggesting that BiN by exclusion is a distinguished level of complexity in BiN.

Interventions to Induce Bidirectional Naming

Similar to other learning capabilities that are also verbal behavior cusps, BiN presents an embedded reinforcer value for one to learn the joint stimulus control for two or more previously unrelated stimuli (Greer, 2019). The embedded reinforcer functions to select one's observing responses. Therefore, when a child experiences novel names of objects, he learns the relation between the name and object without direct reinforcement or instruction. Several researchers found effective protocols to induce BiN as a capability for children who did not have this verbal behavior cusp in their repertoires: Stimulus-stimulus pairing (Longano, 2008), multiple exemplar instruction (MEI; Fiorile & Greer, 2007; Greer et al., 2007), intensive tact instruction (ITI; Costa & Pelaez, 2014; Hotchkiss, 2019; Pistoljevic, 2008), establishing conditioned reinforcers for observing and speaker responses (Longano & Greer, 2008), and repeated probe conditions (Kleinert, 2018; Lo, 2016).

Multiple Exemplar Instruction. Several researchers used MEI across listener and speaker response topographies to evoke the emergence of BiN (Fiorile & Greer, 2007; Gilic & Greer, 2011; Greer et al., 2007) in children with and without disabilities who were as young as two years old. In MEI, the target response topography rotates across match, point, pure tact, and impure tact (Greer & Ross, 2008).

Greer and colleagues (2007) demonstrated the effects of the rotation across listener and speaker behaviors on inducing BiN by comparing the intervention of single exemplar instruction (SEI). In SEI, the researchers delivered instruction in blocks of target response topography. The researchers taught match responses to mastery, then point responses to mastery, and so on across four topographies instead of rotation of target behaviors within the session of instruction. The results showed that the participants under the MEI condition acquired BiN. In contrast, the participants in the SEI condition did not, demonstrating the effects of MEI in joining the listener and speaker responses. In the following experiment, the researchers conducted a cross-over design to test the effects of SEI and MEI within the individual. Participants who previously did not demonstrate BiN after SEI acquired BiN following MEI.

Fiorile and Greer (2007) also used MEI to induce BiN in preschool students with Autism. The researchers taught the stimuli sets to mastery in both listener and speaker topographies. The listener responses were taught in the match and point-to topographies. The speaker responses were taught as pure tact (under the control of visual stimulus) and intraverbal tacts. These target responses were rotated during instruction. Following the MEI as an intervention, all participants emitted correct responses to the stimuli in untaught topographies.

Intensive Tact Instruction. Intensive tact instruction (ITI) is also effective in inducing BiN according to past research (Costa & Pelaez, 2014; Delgado & Oblak, 2007; Greer & Du, 2010; Pistoljevic & Greer, 2006; Schaufer & Greer, 2006). In ITI, the participant receives 100 tact learn units (Albers & Greer, 1991) in addition to his typical instruction. In the learn unit, the student receives reinforcement with vocal praise for correct responses. In contrast, the instructor corrects an incorrect response by modeling the correct response, the student emitting an echoic and an independent opportunity to respond following the echoic. The student contacts reinforcement at a significantly higher rate due to the increase in the number of learn units.

Recently, Hotchkiss (2019) tested the efficiency of ITI protocol by conducting a parametric analysis. She designed an accelerated version of ITI by delivering 50 daily tact learn units instead of 100 daily tact learn units. The results showed that the students who demonstrated

UniN at the onset of the study acquired BiN more efficiently, requiring fewer learn units, under accelerated ITI protocol using 50 learn units. However, the students who had NiN at the onset of the study did not demonstrate a significant difference or efficiency between accelerated and classic ITI protocols. Therefore, Hotchkiss suggested using 50 learn units in the ITI protocol may be more cost-efficient for students who already demonstrate UniN.

Conditioned Reinforcement for Observing Responses. For children who have BiN in their verbal behavior repertoires, the correspondence between seeing and saying functions as a conditioned reinforcer, facilitating incidental language acquisition. In three experiments, Longano and Greer (2006) tested the effects of second-order classical conditioning and echoic behavior on the level of a correct listener and speaker responses during Naming probes. The researcher implemented an MEI procedure with an echoic component, requiring the participant to echo the researcher's tact during the listener topography (i.e., match, point) portion of the intervention. For the participants who did not acquire BiN using MEI, the researcher implemented a stimulus-stimulus pairing, second-order classical conditioning, a procedure to condition a neutral stimulus (i.e., vocal speech) to a previously conditioned stimulus (i.e., picture). The study results suggest the source of BiN may originate from the embedded reinforcement value of joining the auditory (i.e., hear-say) and visual stimuli.

Cao and Greer (2018) tested the effects of echoic training on the demonstration of BiN in a non-native language. Prior to the intervention, the researchers identified Chinese phonemes that the monolingual English-speaking participants did not echo correctly. These phonemes were selected as targets for the participants to learn in the following experiment. In the second experiment, the researchers taught correct echoic production for a set of speech sounds in Chinese to students whose primary language was English and did not have previous exposure to the Chinese language. Following the mastery of the speech sounds, the participants who previously did not demonstrate BiN using the same set of sounds showed the joining of mastered echoic sounds and visual stimuli. When a probe was conducted using novel pairs of visual and auditory stimuli using Chinese characters, the participants continued to demonstrate BiN in the Chinese language.

Repeated Probe. Lo (2016) conducted three experiments to test the effects of multiple probes for BiN on the acquisition of BiN for students who had UniN in their repertoire. Lo stated that the presence of UniN is an indicator that the visual stimuli functioned as a conditioned reinforcer for observing. Conversely, the students did not have the speaker component of naming because the auditory stimuli did not function as conditioned reinforcers for listening. Therefore, she implemented repeated pairing procedures of visual and auditory stimuli through repeated probe sessions for BiN. All participants in Lo's second experiment showed an increase in the number of correct responses to the BiN probes with novel stimuli as a result of repeated probe sessions.

Kleinert (2018) tested the effects of repeated probe procedures on the emergence of BiN across familiar and non-familiar stimuli. After finding a statistical difference in the presence and degree of BiN between familiar and non-familiar stimuli in her first experiment, she implemented repeated probe procedures using a specific pairing method. The researcher delivered an intervention of repeated pairings involving probe presentations following presentations of target 2D stimuli. Following the intervention, all participants in her second experiment acquired BiN for both familiar and non-familiar stimuli.

In the current study, I reestablished the term "repeated probe" as repeated novel naming experience (RNNE) to clarify the difference between presenting novel naming experience sets for each probe session and presenting one set of naming experience until the student reaches 80% criterion level on a probe session. Therefore, RNNE in the current study used a novel set of naming experience stimuli in each probe session.

Effects of Bidirectional Naming on Teaching

Depending on one's degrees of BiN (i.e., listener, speaker, joint BiN), how children should be taught should change to increase the efficiency in learning. Researchers (Greer et al., 2011; Hranchuck et al., 2019) found that it is more effective to teach using antecedent instruction with models for students who have BiN in their repertoire. This is a critical finding because most of the instruction delivered by non-scientifically trained teachers in a typical classroom is dependent on antecedent stimuli presentations rather than delivering consequence stimuli, alone or in combination. In a general education setting, the teacher models and provides spoken and written instructions providing exemplars of the target response and expects the students observing the teacher's behavior to learn through the model. The researchers showed that only those students who demonstrated BiN learned faster through the model. The absence of BiN suggests the need for direct consequences during instruction for the students to learn (Abdool-Ghany, 2020).

Greer and colleagues (2011) identified that students who demonstrate BiN learn faster when taught using a model. They recruited students who demonstrated BiN, UniN (i.e., unidirectionality to the emergence of the untaught listener, only), and No incidental naming (NiN). The same objectives were taught across the students demonstrating the same level of BiN. They compared students' rate of learning for math objectives when taught using standard learn units (SLU; Albers & Greer, 1991) versus model learn unit (MLU). An SLU is an interlocking three-term contingency between a teacher and a student, composed of teacher delivered antecedent, student's opportunity to respond, and appropriate consequence (i.e., reinforcement or correction) delivered the student by the teacher (Albers & Greer, 1991). They found that all students who demonstrated BiN and one student who demonstrated UniN learned faster when taught using MLU. The students who demonstrated UniN or NiN did not show a significant difference in the rate of learning when taught using MLU or learned at a faster rate when taught using SLU (Greer et al., 2011).

When students demonstrated BiN, they not only learned faster but also emitted a higher number of correct responses in their first instructional trials and sessions across multiple reading and math objectives (Hranchuk et al., 2019). Like the previous study, the experimenters used instructional demonstration learn units (IDLU; Hranchuck et al., 2019) and SLU to teach reading and math objectives to students who demonstrated BiN. All participants in their study demonstrated BiN at the onset of the experiment. When taught using the IDLU, all students learned faster, requiring fewer learn units to meet an objective across reading and math. Additionally, the researchers measured participants' percentage of accurate responses in the first instructional trial and session in SLU and IDLU conditions. While the mean percentage correct response for the first instructional trial was 0% across all participants, they demonstrated at least 40% correct response in the first trial only after observing the IDLUs. When the first instruction sessions were analyzed, all participants had a higher mean for percent correct when taught using IDLUs. The evidence from past studies suggests that students must acquire BiN to maximize their learning, especially in a general education setting where they are expected to learn by observing the teacher's model. As shown in the scientific literature (Corwin & Greer, 2017; Greer et al., 2011; Hranchuk et al., 2019;), the acquisition of BiN accelerates students learning by allowing students to learn by observing, instead of needing direct consequences during instruction.

Designing Instruction Based on Student's Degree of Bidirectional Naming

Based on the previous research, we should differentially design instruction depending on the target students' degree of BiN. Weber and colleagues (2020) developed CABAS® STEM Math and CABAS® Reading, a curriculum package applying the principles of how children learn depending on their demonstration of the degree of BiN. The curriculum contained two content areas, reading and math, with objectives aligned to Common Core State Standards (2010) for kindergarten students. They differentiated the target topography of students' responses across students' demonstrated degree of BiN. There are three different tracks in each content area which are NiN, UniN, and BiN.

The NiN track (see Figure 2) of the curriculum is designed for students who demonstrate no-incidental naming. Past research showed that students demonstrating NiN learned faster when taught using SLU (Albers & Greer, 1991), which delivered direct consequences following each student response (Greer et al., 2011). In the NiN track of the curriculum, the students' response topographies include both listener/selection (i.e., match, point-to) and speaker/production (i.e., tact, intraverbal tact, quantity production, writing). All student responses receive a direct consequence of reinforcement or a correction procedure using learn units (Albers & Greer, 1991). Applying the principles of MEI (Fiorile & Greer, 2007) to induce BiN, the NiN track rotates target student response topographies between listener and speaker.

Topography	Listener				Speaker			
Teacher script	Point to the letter that makes the /s/ sound in the word “sit”	Point to the letter that says /a/	Point to the letter that says /t/ in the word ”cat”	Point to the word “sam”	Does this letter say /m/?	What is the missing sound for the word “at”?	What sound does this letter make in the word “tim”?	What sound does this letter make?
Presentation	s i t	s t a	c a t	ham sam pam	m	t	t i m	i
Student response	Points to “s”	Points to “a”	Points to “t”	Points to “sam”	Student says “/m/”	Student says “/a/”	Student says “/t/”	Student says “I”

Figure 2. A sample structure of NiN track instruction in CABAS Reading Unit 4.

The UniN track (see Figure 3) of the curriculum is designed for students who demonstrate unidirectional naming. According to Abdool-Ghany (2020), students who demonstrated the UniN degree of BiN derived untaught listener responses with high accuracy when taught using speaker topographies but demonstrated a low accuracy of derived untaught speaker responses taught using listener topographies. In the CABAS Reading and CABAS STEM Math, this principle was applied to design instruction for students who demonstrated UniN. Additionally, the UniN track embedded an instructional design to increase students' speaker responses. This design stemmed from the ITI (Delgado & Oblak, 2007; Hotchkiss, 2019) to induce BiN for students already demonstrating UniN. The UniN track of the curriculum aims to teach academic content while inducing BiN for students demonstrating UniN. In the UniN track, the students learn to produce speaker or production topographies. Following the mastery of the lesson, the students receive a post-test to test for derived untaught listener responses. If the student does not perform 80% or higher accuracy on the listener response post-test, the student receives direct instruction for listener response topographies.

Topography	Speaker			
Teacher script	How many smiley faces?	(no vocal antecedent)	Show me 3	(point to three triangles) Are there three triangles in this group? (point to two squares) Are there three squares in this group? (point to four circles) Are there three circles in this group?
Presentation		5	(provide 3D manipulatives)	
Student response	Student says: “4”	Student says “5”	Student displays 3 objects	Student says: “Yes” “No” “Yes”

Figure 3. A sample structure of UniN track instruction in CABAS STEM Math Unit 2

The BiN track (see Figure 4) of the curriculum is designed for students who demonstrate bidirectional naming. Past research (Corwin & Greer, 2017; Greer et al., 2011; Hranchuck et al., 2019) showed that students who demonstrated BiN learn at a faster rate when taught using IDLUs. Additionally, students demonstrating BiN showed a high accuracy of untaught derived speaker responses when taught using listener topographies (Abdool-Ghany, 2020). Applying the research results, students assigned to the BiN track of instruction receive IDLUs for each targeted objective. Following the IDLU, the students learned using listener topography responses. When they demonstrate mastery of the lesson, the students receive a post-test to assess derived untaught speaker responses. If the student does not perform at 80% or higher accuracy on the speaker response post-test, the student receives direction instruction speaker response topographies.

Figure 5 displays the differentiated sequence of curriculum based on students' degree of BiN.

Topography	IDLU					Speaker			
Teacher script	This letter says /m/	This letter says /a/	This letter says /s/	This letter says /t/	This letter says /i/	Does this letter say /m/?	What is the missing sound for the word “at”?	What sound does this letter make in the word “tim”?	What sound does this letter make?
Presentation	m	a	s	t	i	m	t	t i m	i
Student response						Student says “/m/”	Student says “/a/”	Student says “/t/”	Student says “I”

Figure 4. A sample structure of BiN track instruction in CABAS STEM Reading Unit 4

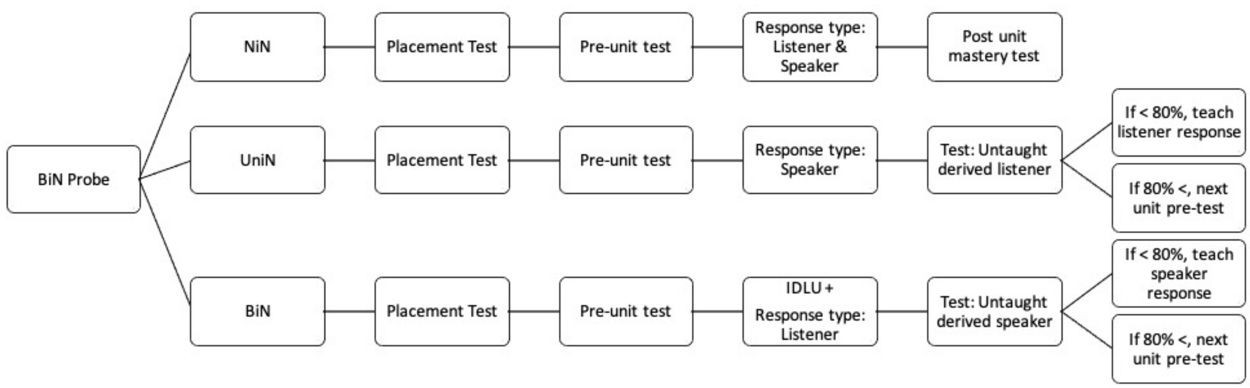


Figure 5. The sequence of CABAS STEM Math and CABAS Reading

Distinguishing Features of CABAS STEM Math and CABAS Reading. Most curricula to teach reading and math are designed for a teacher to demonstrate the target response with independent opportunities for the students to respond. However, not all students can learn from teacher model alone. The CABAS curricula deliver instruction based on how the learner acquires novel information. Based on the student’s degree of BiN, the instructor determines whether the student needs listener, speaker, or rotation of listener and speaker responses during instruction. During the instruction, regardless of the target topography of instruction, the students receive instruction using learn units (Albers & Greer, 1991). A learn unit consists of a clear antecedent from the instructor, an opportunity for the student to respond, and a contingent delivery of consequence (i.e., reinforcement or correction) to the student's response. Therefore, unlike widely used published curricula, the CABAS curricula are not only designed for the students to learn based on their verbal behavior repertoires, but also provide immediate consequences to the students' responses.

Rationale for the Study

Numerous studies have identified effective interventions to induce BiN: 1) MEI, 2) conditioned reinforcement for visual and auditory stimuli, 3) ITI, and 4) repeated probe. Among the interventions, the results of repeated probe interventions demonstrated the cost efficiency of inducing BiN in the most recent years of research. However, previous researchers who tested the effects of repeated probes used non-academic related stimuli. Suppose we could find interventions to induce BiN using academic instruction by designing a curriculum based on the past structure of interventions (e.g., MEI, ITI, repeated probe) already shown to induce BiN. In that case, we can maximize students' learning beyond the effects of inducing BiN alone. If an academic curriculum can induce BiN, the child will acquire BiN cusp while simultaneously learning academic objectives.

I sought to implement academic curricula designed to establish BiN and teach reading and mathematics objectives aligned to CCSS. I used CABAS® STEM Math (Weber et al., 2020) and CABAS® Reading (Weber et al., 2020) aligned to prekindergarten and kindergarten common core state learning standards (Common Core Standards Initiative, 2010). These curricula were also systematically designed to test for the increments of students' level of BiN for students who previously did not demonstrate joint listener and speaker incidental BiN following a novel experience. There are three tracks to each subject within the curriculum based on the students' degree of BiN. In the current study, all participants received instruction under the

Unidirectional naming (UniN) track of the curriculum, given their degree of BiN prior to the study.

In the UniN track of reading and math curricula, the lessons were designed to require speaker response topographies. Previous studies found that adding 100 speaker topography learn units through picture tact instruction to students' instruction, Intensive Tact Instruction (ITI), demonstrated an increase in students' degree of BiN (Delgado & Oblak, 2007; Greer & Du, 2010; Lydon et al., 2007; Pistoljevic & Greer, 2006). More recently, Hotchkiss and Fienup (2020) found that students who previous demonstrate UniN level of naming acquired BiN at criterion level (i.e., 80% or higher accuracy across listener and speaker responses) following a novel experience with an accelerated ITI, which used 50 tact learn units instead of 100. In CABAS® reading and math curricula, the instruction instructional design emulates the effects of ITI by utilizing speaker learn units embedded in reading and math instruction instead of tact instruction using pictures.

I compared a repeated novel naming experience (RNNE), a repeated probe intervention, using a novel set of stimuli for each probe, and the academic curricular intervention's effects on preschool students' degree of BiN (i.e., incidental BiN).

In Experiment I, I asked the following research question:

1. Can a curricular-based intervention that incorporates increased speaker learn unit components induce BiN?

In Experiment II, I asked the following research questions:

1. Are there different effects between a curricular-based intervention and repeated novel naming experience (RNNE) in inducing BiN across two levels of complexity for preschool students?

2. Does the method of intervention for the emergence of BiN have a different effect on preschool student's rate of learning, measured using learn units to criterion (LUC)?
3. Does the method of intervention for the emergence of BiN have a different effect on the number of correct responses to unconsequated post unit tests?

CHAPTER II

EXPERIMENT I: IMPLEMENTING A CURRICULUM-BASED INTERVENTION TO INDUCE BIDIRECTIONAL NAMING

Method

Participants

The participants were four prekindergarten, 4-year-old, students attending a public elementary school in a suburban town. All participants were recruited from a classroom utilizing CABAS/AIL (Comprehensive Application of Behavior Analysis to Schooling/Advanced Independent Learner) model of instruction (Greer, Keohane, & Healy, 2002; www.cabasschools.org; scienceofteaching.org). The participants were enrolled in a prekindergarten CABAS/AIL classroom located in a publicly funded elementary school in a suburban town. The classroom consisted of 16 students, one teacher, and two teaching assistants. Participant A was a male student with an Individualized Education Plan (IEP) classification of Preschooler Child with a Disability. Participants A, C, and D were categorized as English Language Learners (ELL). All participant demonstrated unidirectional level of naming (UniN) in pre-experiment probes. Additional information on participants can be found in Table 1.

Table 1. *Demographical information, educational classification, and relevant verbal behavior cusps of participants in Experiment I.*

Participant	Chronological Age*/Grade	ELL	IEP	FRL	Degree of BiN*
A	4.11/PK	Y	Y	Y	UniN
B	4.1/PK	N	N	N	UniN
C	4.2/PK	Y	N	Y	UniN

D	4.6/PK	Y	N	N	UniN

Note. ELL=English language learner; IEP=Individualized education plan; FRL=free/reduced lunch; BiN=bidirectional naming; UniN=unidirectional naming; *=at the onset of study.

Setting and Materials

All sessions of the current study were conducted in participants' classroom. The sessions occurred at a child-height horseshoe table (i.e., U-shaped) with four child-sized chairs around the table.

For the pre- and post-intervention probes, the researcher used 10.16 cm by 15.24 cm index cards containing 2D pictorial representations of cartoon characters (see Figure 6). Each set of probe stimuli consisted of five different characters with four exemplars per character. In curriculum-based intervention, the researcher used CABAS® STEM Math (Weber et al., 2020) and CABAS® Reading (Weber et al., 2020). The reading and math curricula (see Figure 7) consisted of a teacher script book and a presentation book containing 2D and text stimuli corresponding to the lessons. Additionally, math manipulatives (e.g., counting bears, Unifix® cubes), dry-erase boards (30.48 cm by 22.86 cm), and dry-erase markers were used during curriculum-based intervention. Figures 8 displays an example of four types of learn units from the reading curriculum. Figure 9 displays an example of four types of learn units from the math curriculum.

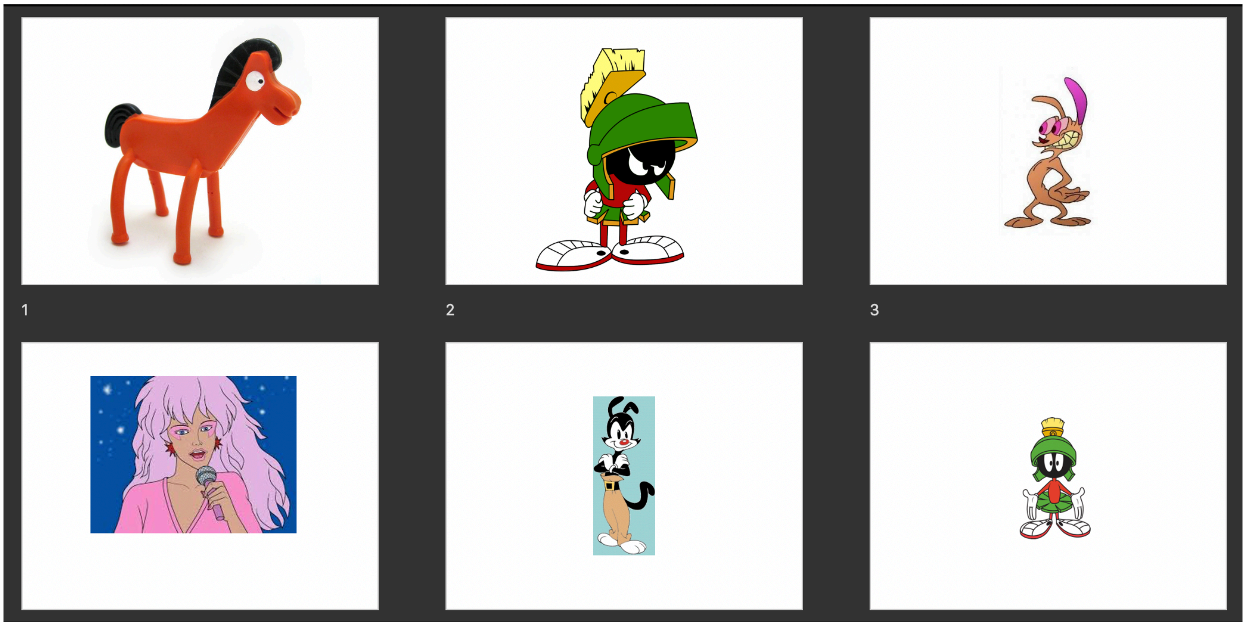


Figure 6. Samples of familiar picture stimuli used in Experiment

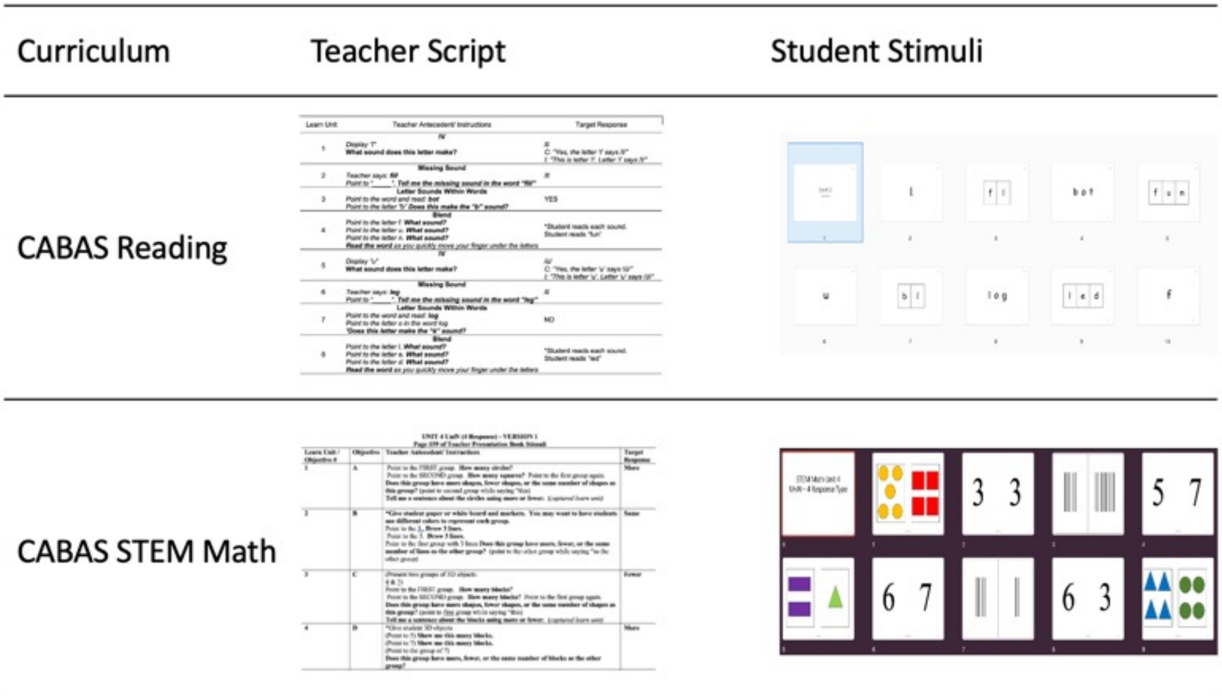


Figure 7. Samples of teacher script and student presentation stimuli for CABAS Reading and CABAS STEM Math curricula used in the experiment.

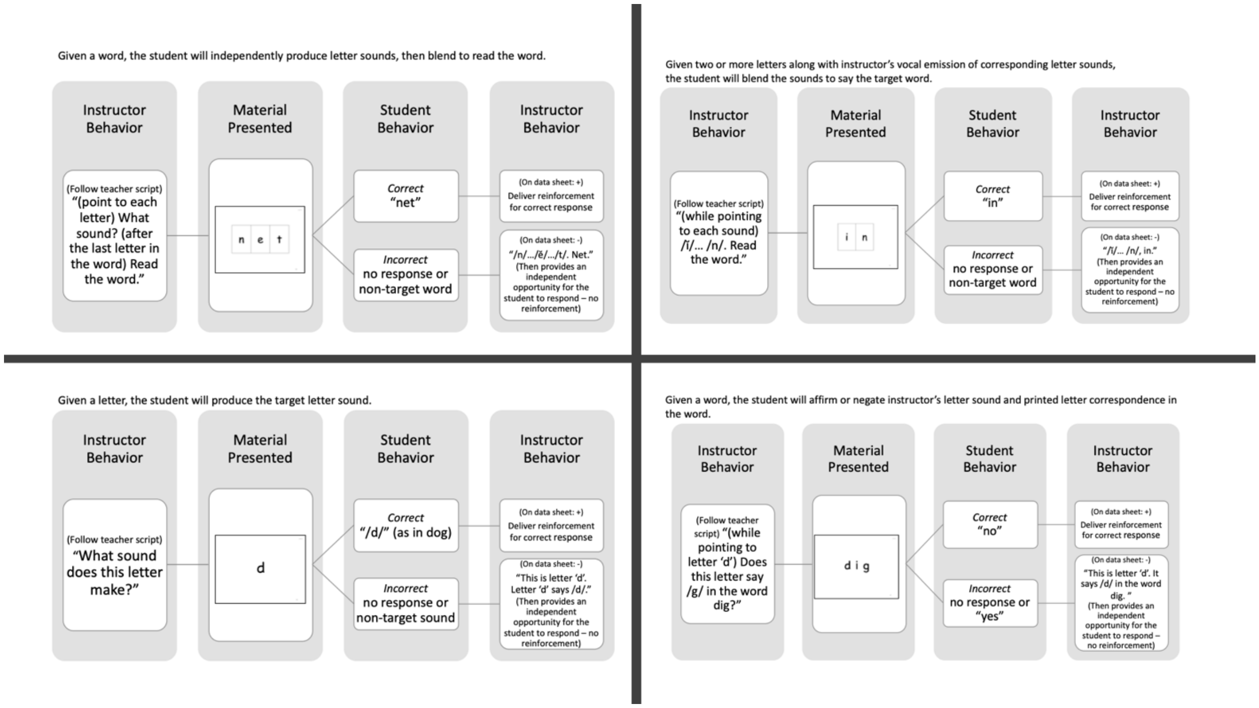


Figure 8. An example of four learn units from CABAS Reading Unit 5.

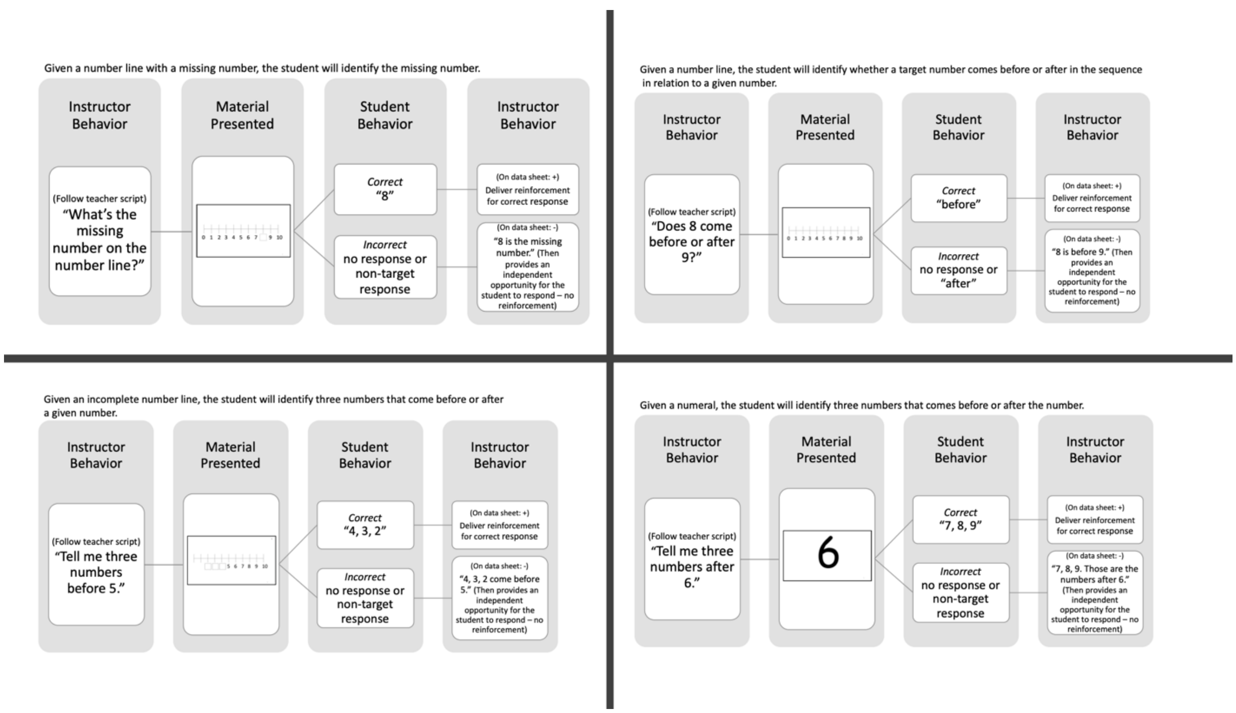


Figure 9. An example of four learn units from CABAS STEM Math Unit 4.

Dependent Variable

The dependent variable was the number of students' correct responses to bidirectional naming (BiN) probes which measured the degree of stimulus control of BiN for familiar picture-word relation level of complexity. The researcher presented a novel experience using 40 picture-words across five target stimuli. At least two hours after the novel experience, the degree of BiN was measured across three topographies which were listener (point-to), tact, and intraverbal tact responses. The criterion for demonstration of BiN was 80% accuracy or higher across all response topographies following a novel experience.

Independent Variable

The independent variable of the study was a curriculum-based instruction designed to induce BiN while simultaneously teaching academic objectives. The instruction consisted of a math and a reading curriculum. These curricula were designed for the student to emit speaker responses for students who demonstrate UniN (i.e., 80% or higher accuracy for listener responses following a novel experience) for familiar picture and word relations. The curricula used were CABAS STEM Math (Weber et al., 2020) and CABAS Reading (Weber et al., 2020). Both reading and math curricula were sequenced to teach five target objectives in each unit. The students had four opportunities, presented using multiple exemplars (i.e., different fonts, visual representations, colors, sequence of presentation), to learn five target objectives. Therefore, each instruction unit was composed of 20 learn units (i.e., five objectives × four opportunities = 20 learn units).

Experiment Design

The researcher used a multiple probe design (see Figure 10) across participants to measure the degree of BiN stimulus control for familiar picture and word relation level of complexity. At the onset of the study, probes were conducted to measure the degree of (i.e., strength of the stimulus control for) BiN for all participants. Participant A entered the curriculum-based intervention after the two sessions of pre-intervention probes. Participant B entered the intervention following three sessions of pre-intervention probes. The third pre-intervention probe was chronologically aligned to Participant A's first post-intervention probe. Participant C entered the intervention following four sessions of pre-intervention probes. The fourth pre-intervention probe was chronologically aligned to Participant B's first post-intervention probe. Participant D entered the intervention following four sessions of pre-intervention probe. Participant D's fourth pre-intervention probe was chronologically aligned to Participant C's first post-intervention probe.

A post-intervention BiN probe was conducted immediately after the participant met criterion for the curricular-based intervention (i.e., demonstrate mastery criterion for both reading and math units). The criterion level of both units was 90% correct response across two consecutive sessions or 100% correct response in one session. If the participant met criterion for reading but not for math, math instruction was repeated twice to fulfill the 40 learn unit quota, and vice versa. This sequence of probes and intervention continued until the participant demonstrated 80% or higher accuracy in BiN probe responses following a novel experience.

Participant	Sequence of Experiment															
A	Pre-intervention Probe 1	Pre-intervention Probe 2	Curriculum intervention 1	Post-Probe 1	Curriculum intervention 2	Post-Probe 2	Curriculum intervention 3	Post-Probe 3								
B			Pre-Probe 3	Pre-Probe 4	Curriculum intervention 1	Post-Probe 1	Curriculum intervention 2	Post-Probe 3	Curriculum intervention 3	Post-Probe 3	Curriculum intervention 4	Post-Probe 4				
C				Pre-Probe 3		Pre-Probe 4	Curriculum intervention 1	Post-Probe 1	Curriculum intervention 2	Post-Probe 3	Curriculum intervention 3	Post-Probe 3	Curriculum intervention 4	Post-Probe 4		
D						Pre-Probe 3		Pre-Probe 4	Curriculum intervention 1	Post-Probe 1	Curriculum intervention 2	Post-Probe 3	Curriculum intervention 3	Post-Probe 3	Curriculum intervention 4	Post-Probe 4

Figure 10. The sequence a multiple probe design across participants in Experiment I. Grey boxes indicate pre-intervention probes. Diagonal black lined boxes indicate curriculum intervention.

White boxes indicate post-intervention probes. Black boxes indicate phases in which the participant did not receive any intervention or probe sessions.

Procedure and Data Collection

Pre- and Post-Intervention Bidirectional Naming Probes

The probe sessions were composed of two parts, a novel naming experience and test for untaught responses. In both parts of the probes, the participant sat at a child-sized horseshoe table, while the researcher sat across the table from the participant in the inner curve of the horseshoe table. The researcher ensured that the participant had an establishing operation in place (e.g., receive social praise from the researcher for in-seat behavior) to attend to the stimuli. Then the researcher presented 2D representations of cartoon characters on index cards. Prior to the novel experience, the researcher presented each stimulus (i.e., cartoon character) to the participant and asked "what/who is this?" to ensure the names of target operants (i.e., cartoon characters) were not in participants' repertoires. If the participants did not have any of the target operants in repertoires, the researcher proceeded to novel experience. If the participant had the name of any of the operants in repertoires, the researcher used a completely different set of stimuli that was not in students' repertoires. The screening of sets continued until the researcher identified a set of stimuli that consisted of characters that were novel to the participant.

In the novel experience, the researcher presented 2D stimuli on the table or at the participant's eye-level while simultaneously emitting a vocal tact of the name that corresponds to the presented stimulus. The researcher maintained the 2D stimulus for 2 s at the participant's eye-level after saying the name of the stimulus. There was a total of five target operants (i.e., cartoon characters) with four non-identical visual versions (i.e., variations in irrelevant visual properties (e.g., character running, sitting, standing) of each target stimulus. The participants were exposed to the pairing of spoken name and picture stimuli presented by the researcher. The participant experienced two pairings of spoken name and picture per stimulus. Therefore, the total number of experience trials was 40 (i.e., 5 target stimuli × 4 exemplars × 2 exposure trials = 40 trials), to match the number of instructional trials the participants received in the intervention. Following the novel experience, the researcher waited at least 2 hr to conduct a test to measure participants' accurate response to the probe.

In the post-novel experience probe, there were three target response topographies. To measure the listener half (i.e., demonstration of UniN), the researcher presented two non-exemplars and one target-exemplar stimuli cards on the table. Then the researcher delivered a vocal antecedent "Point to (target exemplar)." A correct response, marked with a plus (+) on a data sheet, was defined as the participant pointing to the target exemplar within 2 s of the vocal antecedent delivery, while an incorrect response, marked with a minus (-), was defined as the participant pointing to a non-exemplar or an absence of response within 2 s of the antecedent. Following the listener probe, the researcher measured participants' accuracy of speaker responses. To measure the speaker component of BiN, the researcher collected data for the number of correct tact and intraverbal tact responses emitted by the participant under a given antecedent. For tact responses, after ensuring that the participant was attending to the researcher and presented stimulus, the researcher displayed the target stimulus at the participant's eye-level or on the table without a vocal antecedent. For intraverbal tact responses, the researcher presented the target 2D stimulus with a vocal antecedent, "who/what is this?". A correct speaker response was defined as the participant's emission of the target tact (i.e., name of the picture as presented by the researcher in novel experience) within 2 s of the antecedent delivery. An incorrect speaker response was defined as participants' emission of an incorrect tact response or an absence of response within 2 s of the antecedent delivery. There were 10 opportunities for each response topography (i.e., total of 30 probe trials) as the participant was presented with two opportunities per response topography for each target operant. All probe trials across the topographies were unconsequated. The criterion for the presence of UniN was 80% or higher accuracy of listener response following the novel experience. The criterion for the presence of BiN was 80% or higher accuracy of all response topographies in the probe following the novel experience.

Curriculum-based Intervention

The participants received a daily total of 40 learn units of speaker topography using the UniN track of CABAS STEM Math (Weber et al., 2020) and CABAS Reading (Weber & Greer, 2020) curricula. The instruction only included speaker responses because all participants previously demonstrated UniN. The instruction criterion for all units in both curricula was set at 90% accuracy across two consecutive sessions or 100% accuracy in one session, delivered using a 20-learn unit (Greer & Hogin-McDonough, 1999) instruction session. The researcher followed corresponding teacher scripts and presentation materials throughout the intervention. However, all instruction trials were delivered using learn units (Albers & Greer, 1991). A learn unit is an interlocked three-term contingency between the instructor and the student's behaviors. In a learn unit, the teacher ensures the student is attending and an establishing operation is in place for the student to attend to instruction. Then, the teacher delivers the antecedent to the student. The student responds to the teacher's antecedent. If the student emits a correct response, then the teacher delivers a reinforcement (e.g., vocal praise, tokens, edibles). If the student emits an incorrect response, the teacher delivers a correction procedure. In the correction procedure, the teacher presents the correct response to the student and re-presents the antecedent for an independent opportunity for the student to respond. The student's correct response following a correction procedure is not reinforced.

If the participant met criterion for one subject (i.e., reading or math) but did not for the other subject, the researcher delivered instruction for the unmet subject twice to ensure the participant received 40 learn units of speaker responses per day.

Interobserver Agreement

Interobserver agreement (IOA) and treatment integrity data were collected using the teacher performance rate and accuracy (TPRA; Ingham & Greer, 1992). All individuals conducting probes and delivering instruction received at least three, consecutive, errorless TPRAs on BiN probes and intervention sessions by the first author to ensure treatment integrity. Interobserver agreement was collected for 3% of the intervention sessions and 16% of the probe sessions with a mean agreement of 100%.

Results

In the pre-curriculum-based intervention probes (see Figure 11), Participant A emitted 80% and 100% correct listener, 0% and 60% correct tact, and 0% and 60% correct intraverbal tact responses across two pre-intervention probes. Participant B emitted 60%, 70%, 60%, and 90% correct listener, 0%, 60%, 40%, and 40% correct tact, and 0%, 60%, 40%, and 40% correct intraverbal tact responses across four pre-intervention probes. Participant C emitted 70%, 80%, 50%, and 80% correct listener, 20%, 0%, 10%, and 0% correct tact, and 20%, 0%, 20%, and 0% correct intraverbal tact responses across four pre-intervention probes. Participant D emitted 80%, 100%, 80%, and 80% correct listener, 20%, 30%, 20%, and 20% correct tact, and 20%, 40%, 20%, and 20% correct intraverbal tact responses across four pre-intervention probes.

Following the first phase of curriculum-based intervention, Participant A emitted 90% correct listener, 10% correct tact, and 0% correct intraverbal tact responses, while Participant B emitted 80% correct listener, 40% correct tact, and 40% correct intraverbal tact responses. Participant C emitted 80% correct listener, 30% correct tact, and 20% correct intraverbal tact responses in the first post-intervention probe. Participant D emitted 100% correct listener, 60% correct tact, and 40% correct intraverbal tact responses after the first intervention.

In the second post-intervention probe, Participant A emitted 100% correct listener, 60% correct tact, and 50% correct intraverbal tact responses, while Participant B emitted 80% correct listener, 40% correct tact, and 40% correct intraverbal tact responses. Participant C emitted 100% correct listener, 20% correct tact, and 10% correct intraverbal tact responses in the second post-intervention probe. Participant D emitted 100% correct listener, 40% correct tact, and 40% correct intraverbal tact responses after the first phase of intervention.

Following the third phase of curriculum-based intervention, Participant A emitted 100% correct listener, 90% correct tact, and 80% correct intraverbal tact responses, demonstrating the presence of BiN (i.e., at least 80% accuracy across all topographies) for familiar picture and word relations. Participant B emitted 100% correct listener, 80% correct tact, and 80% correct intraverbal tact responses, also demonstrating the presence of BiN for familiar picture stimuli. In the third post-intervention probe, Participant C emitted 100% correct listener, 40% correct tact, and 50% correct intraverbal tact responses, while Participant D emitted 100% correct listener, 70% correct tact, and 80% correct intraverbal tact responses.

Following the fourth phase of intervention, Participant C emitted 100% correct listener, 80% correct tact, and 80% correct intraverbal tact responses, demonstrating the presence of BiN (see Figure 11).

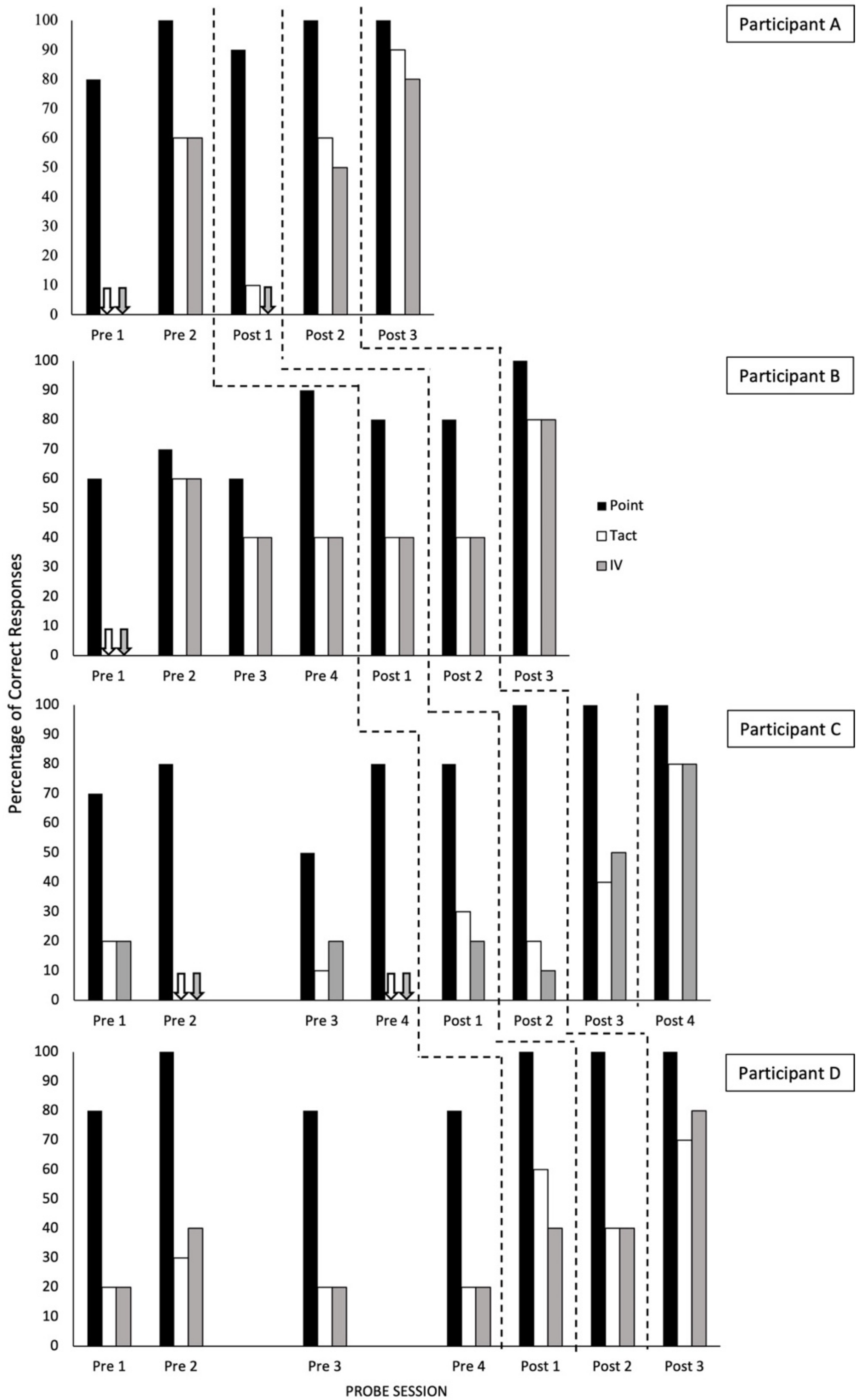

Participant A
Participant B
Participant C
Participant D
Point
Tact
IV
Percentage of Correct Responses
PROBE SESSION
Pre 1
Pre 2
Pre 3
Pre 4
Post 1
Post 2
Post 3
Post 4

Figure 11. Pre- and post-intervention data across four participants in Experiment I. Dotted lines between probe sessions indicate intervention phases. Black bars represent the percentage of correct point responses. White bars represent the percentage of correct tact responses. Grey bars represent the percentage of correct intraverbal tact responses.

Discussion and Rationale for Experiment II

The results from Experiment I demonstrated the possibility of a curriculum-based intervention on increments of stimulus control for BiN at familiar word-picture level of complexity, following novel experiences. Participant A demonstrated BiN criterion level of at least 80% accuracy across three topographies after three intervention phases. Participant B and C demonstrated BiN following four intervention phases. Participant D received four intervention phases. In the final post-intervention probe, Participant D demonstrated a mean of 75% accuracy (range, 70% to 80%) across speaker responses (i.e., tact, intraverbal tact), which was 5% less than the criterion level of 80%. Participant D could not receive an additional intervention phase due to the onset of the COVID-19 pandemic.

A limitation in the first experiment is the ascending trend in pre-intervention probe demonstrated by Participant A. While Participants B, C, and D have a stead baseline data prior to entering the intervention, Participant A's responses in probe sessions increased from 80%, 0%, and 0% in the first probe to 100%, 60%, and 60% correct listener, tact, and intraverbal tact responses in the second probe without any intervention. The data show that Participant A may not have needed the intervention but may have acquired BiN with additional BiN probe sessions alone (Kleinert, 2018).

Another limitation in Experiment I is the number of sessions IOA was collected for. Due to the limited availability an independent observer during live sessions, conducted during a regular school day, an insufficient number of probe and instruction sessions were observed for IOA. Additionally, the COVID-19 global pandemic prevented IOA collection of additional sessions. Though the agreement between the researcher and the independent observer was at 100%, the low number of sessions with IOA cannot be justified. In Experiment II, the researcher used video recordings to improve the number of sessions with IOA collection.

In Experiment I, the researcher sought to test the effects of a curriculum-based intervention on the degree of BiN. The results showed a steady increase of the degree of BiN across the participants throughout the study in subsequent post-intervention phases. Therefore, this study demonstrated that a curriculum-based intervention can induce BiN while the participants learn math and reading skills. However, Experiment I did not have a control group to compare the effects of the curriculum-based intervention to pre-existing research-based intervention to induce BiN.

In Experiment II, the researcher sought to compare the effects of repeated novel naming experience (RNNE; Kleinert, 2018) and the curriculum-based intervention and how the different methods of intervention to induce BiN may affect students' learning. The purpose of Experiment II was to: (1) investigate possible different effects between a curriculum-based intervention and RNNE in inducing BiN across two levels of complexity; (2) examine possible difference on learn units to criterion (LUC) in reading and math instruction; and (3) study possible effects on the number of correct responses in unconsequated post-unit tests. Unlike Experiment I, Experiment II included a control group (i.e., RNNE), paired with an intervention counterpart in each dyad. Additionally, Experiment II had additional dependent variables of degree of stimulus control for unfamiliar word-picture relation level of complexity, learn units to criterion to measure the rate of learning, and number of correct responses in unconsequated post-unit tests.

CHAPTER III

EXPERIMENT II: COMPARING THE EFFECTS OF A CURRICULUM-BASED INTERVENTION AND REPEATED NOVEL NAMING EXPERIENCE

Methods

Participants

Eight students enrolled in a pre-kindergarten inclusion classroom participated in the study (see Table 2). The class utilized a CABAS/AIL model of instruction (Greer et al., 2002). All participants demonstrated UniN for familiar 2D stimuli (e.g., flowers, insects) according to probes conducted prior to the onset of the intervention. The participants were matched into pairs based on their percentage of accuracy across listener and speaker responses during the pre-intervention probes and their Brigance® scores. The researcher used Brigance inventory for early development III (IES III) to match the participants into dyads. Brigance is a standardized developmental screener, in which a child's physical, language, academic, and cognitive development skills are scored based on a normative sample of children of the same age (Brigance & French, 2013). All participants were screened using the four-year-old screener from the Brigance IES III. The participants were matched into dyads based on their percentile ranks according to the IES III.

Table 2. *Demographical information, educational classification, Brigance score, and degree of BiN of participants in Experiment II.*

Dyad	Participant	Chronological Age[1]	IEP	ELL	FRL	Brigance[2]	Degree of BiN
1	1	4-4	N	N	N	94.5	Incidental Unidirectional Naming
	2	4-10	N	N	N	97	
2	3	4-5	N	N	N	87.5	

	4	4-5	N	N	N	91.5
3	5	4-1	N	N	N	82.5
	6	4-1	Y	N	N	79
4	7	4-10	Y	N	N	52
	8	4-6	Y	N	Y	57

Note. [1]chronological age at the onset of study (year-months); [2]Brigance inventory for early development III (Brigance & French, 2013); IEP=Individualized education plan; ELL=English language learner; FRL=participant receives free/reduced meals from the public-school district; BiN=bidirectional naming; all information reported at the onset of the study.

Setting and Materials

Due to the COVID-19 global pandemic, all probe and intervention sessions were conducted in the cyberspace using online platforms available via Google Chrome (i.e., Google Slides, Pear Deck, Google Meets, Google Classroom). When the participants received in-person instruction in the school building according to the school district's decisions, each participant sat behind individual Plexiglas quarters at a child-sized table assigned to three to four children. When the participants received virtual instruction according to the school district's decision, they were in various places not clearly identifiable to the researcher (e.g., home, vacation cabin). Table 3 displays the percentage of sessions delivered in-home versus in-classroom for each participant.

Table 3. *Percentage of probe, intervention, and total experimental sessions conducted while the participant was not in school (e.g., home, vacation house) due to quarantine related to the COVID-19 pandemic.*

			Percentage of sessions while participant was at home (due to quarantine)		
Dyad	Participant	Condition	Probe	Intervention	Total
1	1	Curriculum	20%	60%	44%
	2	RNNE	10%	12.5%	11.1%
2	3	Curriculum	20%	61.1%	46.4%

	4	RNNE	30%	10%	20%
3	5	Curriculum	18.75%	67.6%	52%
	6	RNNE	14.3%	29.4%	22.6%
4	7	Curriculum	7.1%	21.6%	18.5%
	8	RNNE	100%	100%	100%

All picture-word relation probes, intervention sessions, curricular instruction, and curricular unit tests were delivered using Google Slides. During the probe sessions for familiar stimuli and RNNE condition, the researcher used 2D pictorial representations of objects that the participants may contact in a natural environment but did not know the names of (e.g., plants, animals; see Table 4). Each set of stimuli consisted of one mono-syllabic, three bi-syllabic, and one tri-syllabic words. During the unfamiliar probe sessions, the researcher used logographic symbols or characters of non-Latin-based language (see Table 5). CABAS STEM Math (Weber et al., 2020) and CABAS Reading (Weber et al., 2020) curricula provided curriculum intervention sessions, post-BiN instruction, and unit tests materials.

Table 4. *Samples of familiar picture stimuli used during pre- and post-intervention BiN probes.*

Flower Set 2	Insect Set 1	Tree Set 1
 Zin	 Midge	 Spruce
 Jasmine	 Locust	 Willow
 Iris	 Earwig	 Maple
 Lotus	 Aphid	 Hemlock
 Dahlia	 Cicada	 Betula

Table 5. *Samples of unfamiliar picture stimuli used during pre- and post-intervention BiN probes.*

Set 1	Set 2	Set 3
 Bram	 Ma	 Alch
 Sumeck	 Tzaddik	 Lira
 Flogget	 Zia	 Hera
 Destry	 Grounding	 Ramshorn
 Cazzerly	 Udinkra	 Nemesis

Dependent Variables

There were three dependent variables in the experiment. The first dependent variable was students' correct responses to BiN probes which measured the degree of stimulus control for UniN and BiN for two levels of complexity (i.e., familiar picture-word relations, unfamiliar picture-word relations). The second dependent variable of the study was the number of learn units to criterion (LUC) across reading and math curricula. The third dependent variable of the study was the number of unconsequated correct responses to post-unit tests conducted after the mastery of each unit across reading and math objectives in the CABAS STEM Math and CABAS Reading curricula.

Independent Variables

There were two independent variables in Experiment II. The first independent variable was a curriculum-based intervention using CABAS STEM Math and CABAS Reading (i.e., identical to the independent variable of Experiment I). The second independent variable was the repeated novel naming experience (RNNE).

Design

I used a combined multiple probe logic across dyads and simultaneous treatment (experimental-control paired dyads) design to compare the effect of RNNE-control and curricular-based intervention on the emergence of BiN and effect on LUC following the emergence of BiN (see Figure 12 and 13).

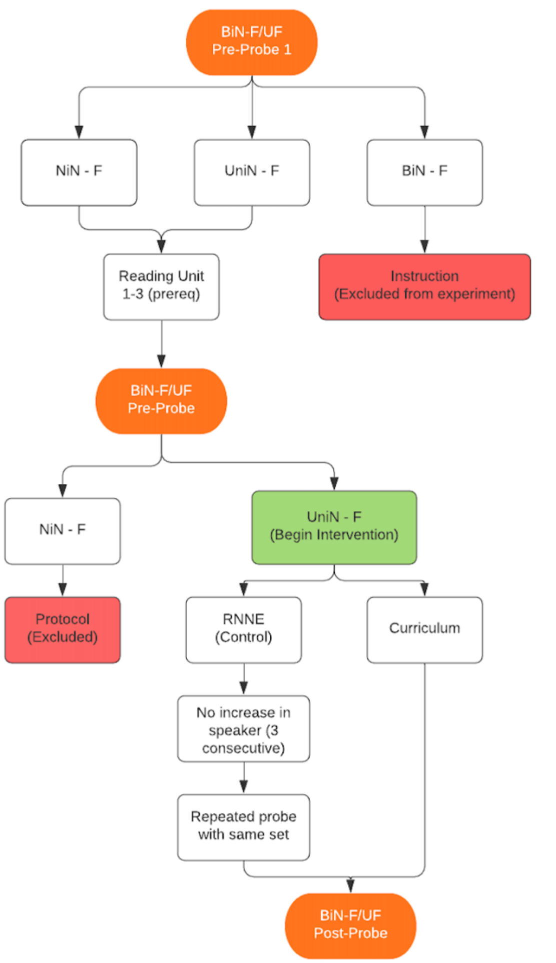


Figure 12. A diagram of the sequence of probes and intervention for each participant in Experiment II.

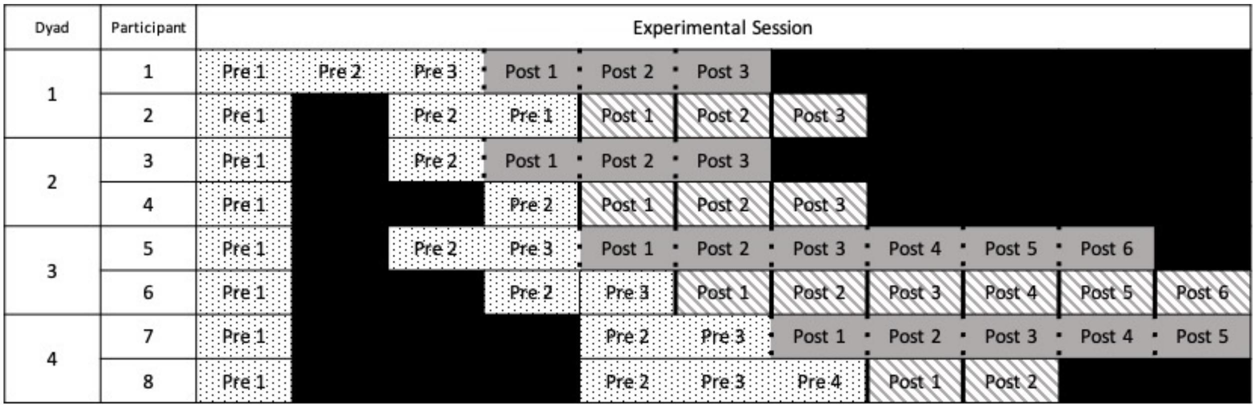


Figure 13. The sequence a multiple probe design across participants within a dyad in Experiment II. Dotted boxes indicate pre-intervention probes. Grey boxes indicate post intervention probes following the curriculum-based intervention. Diagonal black lined boxes indicate post intervention probes following the RNNE intervention. Black boxes indicate phases in which the participant did not receive any intervention or probe sessions. Bolded solid lines indicate RNNE intervention phases. Bolded dotted lines indicate curriculum-based intervention phases.

Procedure and Data Collection

Matching of the Participants

The participants were matched based on their percentile rank score of the Brigance IES III (Brigance & French, 2013) conducted prior to the onset of the study. Participants were matched with another participant who had the smallest difference in percentile rank score in the IES III. Based on the participants' Brigance IES III percentile rank scores, Participants 1 and 2 were assigned to Dyad 1. Participants 3 and 4 were assigned to Dyad 2. Participants 5 and 6 were assigned to Dyad 3. Participants 7 and 8 were assigned to Dyad 4. Participants 1, 3, 5, and 7 received curriculum-based intervention while Participant 2, 4, 6, and 8 received RNNE as intervention. Following the matching with another participant in the dyad, each participant was randomly assigned the curriculum-based or the RNNE condition.

Pre- and Post-Intervention Bidirectional Naming Probes for Picture-Word Relations

While the participants sat in front of their 30.48 cm Chromebooks, they were instructed to access Google Classroom which contained a link to an instructor-paced Pear Deck session for the corresponding set for individual participant. The participants were also on Google Meets, which they accessed using the Google Classroom, for the researcher to ensure that the participant was attending to the stimuli presented on their Chromebook screen. When the participant logged on to the Pear Deck session, the researcher presented each slide containing one target stimulus. To control for lag of antecedent delivery caused by internet, the researcher used GoGuardian to assist the participant to share their screen of Pear Deck session on Google Meets so that the researcher can simultaneously view the participant's screen. While the participant was attending to the 2D stimulus on Google Slide, the researcher delivered a vocal antecedent of the name or word that corresponded to the presented stimulus. The participants were exposed to the pairing of vocal word and picture stimuli presented by the researcher twice for each stimulus. Therefore, the total number of experience trial was 40 (i.e., 5 target stimuli × 4 exemplars × 2 exposure trials = 40 trials). Following the experience, the researcher waited at least two hours to conduct probes to measure participants' accurate responses to the probe.

There were three target response topographies during the probe. To measure the degree of UniN, the researcher presented a slide containing two non-exemplars and one target exemplar. The slide was manipulated using Pear Deck so that the participant could select a response using a draggable icon, which was recorded on the database of Google Drive. The researcher delivered a vocal antecedent "Find (target exemplar)" in the presence of the corresponding slide. A correct response, recorded with a plus (+) on the data sheet, was defined as the participant selecting the positive exemplar by clicking on the picture. An incorrect response, recorded with a minus (-), was defined as the participant selecting a non-exemplar or not emitting a response. To measure the speaker component of BiN, the researcher collected data for the number of correct tact and intraverbal tact responses. For tact responses, after ensuring that the participant is attending to the screen, the researcher presented the target stimulus on the Slide at the participant's view. For intraverbal tact responses, the researcher presented the target stimulus on the Slide with a vocal antecedent, "what is this?" A correct speaker response was defined as the participants' emission of the target tact for the presented stimulus within 2 s of the antecedent delivery. An incorrect speaker response was defined as participants' emission of a non-exemplar tact response or no response within 2 s of the antecedent delivery. There were 10 opportunities to respond for each response topography (i.e., total of 30 probe trials) as the participant was presented with two opportunities per response topography for each target operant. All probe trials across all topographies were unconsequated.

Learn Units-to-Criterion

The participants' LUC was calculated by adding the total number of learn units the participant received to demonstrate mastery criterion level (i.e., 90% accuracy in one session) and dividing the sum of received learn units by the number of criteria (i.e., units) mastered (e.g., $\text{LUC} = \frac{\text{Sum of number of learn untis to mastery criterion}}{\text{Number of criteria mastered}}$). The LUC data were only collected and calculated for the participants under the curriculum-based intervention condition and those who demonstrated BiN for familiar word-picture relations following the intervention.

Unconsequated Responses to Unit Tests

All unit tests were delivered using Google Slides and student-paced Pear Deck sessions. During reading unit tests, the participants received vocal antecedent from the researcher to log on to their assignment using the link provided on Google Classroom. Each slide contained a recorded vocal antecedent, accessible to the participants by clicking on the headphone icon. The data for unit tests were collected using Pear Deck's student response recording function. The number of correct responses to each unit test was converted into percentage correct to control for different number of trials in unit tests between reading and math curricula. The unconsequated responses to unit tests data were only collected and calculated for the participants under the curriculum-based intervention condition and those who demonstrated BiN for familiar word-picture relations following the intervention.

Curriculum-based Intervention

The curriculum-based intervention was conducted in a similar manner as the intervention of Experiment I. However, the presentation stimuli used during instruction were displayed on Google Slides (see Appendix A). Instructional sessions were also delivered via Google Meets in which up to two students participated simultaneously. The researcher shared the screen containing stimuli on Google Slide, intermittently asked the participants if they could see the stimuli, then delivered appropriate vocal antecedents according to the instruction script. A correct and an incorrect response was defined in the script of the curricula. Similar to Experiment I, all instructional trials were delivered using learn units (Albers & Greer, 1991).

Repeated Novel Naming Experience

The RNNE was identical to pre- and post-intervention BiN probes. A new set of stimuli was used in each session. The number of sets the participant received was dependent on the participant's counterpart assigned to the same dyad. That is, the number of Participant 2's RNNE sessions per phase depended on the number of curricular learn units Participant 1 required to meet mastery criterion in each phase. Each RNNE session was composed of 40 naming experiences for familiar picture-word relations. The number of learn units received by the participant receiving the curriculum-based intervention was matched with the number of naming experiences for the participant under the RNNE condition. If the number of learn units for the curriculum-based participant was not a multiple of 40, the number of experiences was rounded up to the nearest 40 to provide 40 experiences per probe session. For example, if Participant 1 received a total of 140 learn units in a phase to meet the mastery criterion for the curriculum-based intervention, Participant 2 received four RNNE sessions, resulting in 160 naming experiences.

Interobserver Agreement

Interobserver agreement (IOA) was collected using video recordings and computer-generated data collection. For all listener responses (i.e., point-to topography), IOA was collected via computer-generated spreadsheet based on participants' responses. Using video recording, IOA was collected for 51.4% of BiN probe sessions with a mean agreement of 97.2% (range 87.5%-100%). Video recording was also used to collect IOA for intervention sessions. IOA was collected for 40% of the intervention sessions with a mean agreement of 94.3% (range 63.3%-100%). Interscorer agreement (ISA) was collected for post-unit tests using computer-generated spreadsheet. ISA was collected for 100% of the unit tests with a mean agreement of 100%.

Results

Dyad 1

Degree of Bidirectional Naming

Familiar Picture-Word Relations. Prior to the intervention, Participant 1 (see Figure 14) emitted 70%, 90%, 90% correct listener, 60%, 70%, 20% correct tact, and 60%, 60%, 20% correct intraverbal responses, while Participant 2 emitted 20%, 50%, 90% correct listener, 0%, 20%, 0% correct tact, and 20%, 20%, 0% correct intraverbal tact responses across three pre-intervention probes.

Participant 1 demonstrated BiN for familiar picture-word relations after three intervention phases. After the first phase, Participant 1 emitted 100% correct listener, 70% correct tact, and 80% correct intraverbal tact responses, while Participant 2 emitted 100% correct listener, 0% correct tact, and 0% correct intraverbal responses. Following the second intervention phase, Participant 1 emitted 100% correct listener, 80% correct tact, and 70% correct intraverbal tact responses, while Participant 2 emitted 90% correct listener, 30% correct tact, and 30% correct intraverbal responses. In the third post-intervention probe, Participant 1 demonstrated the presence of BiN with 100% correct listener, 80% correct tact, and 80% correct intraverbal tact responses. Participant 2 emitted 90% correct listener, 60% correct tact, and 60% correct intraverbal tact responses in the third post-intervention probe.

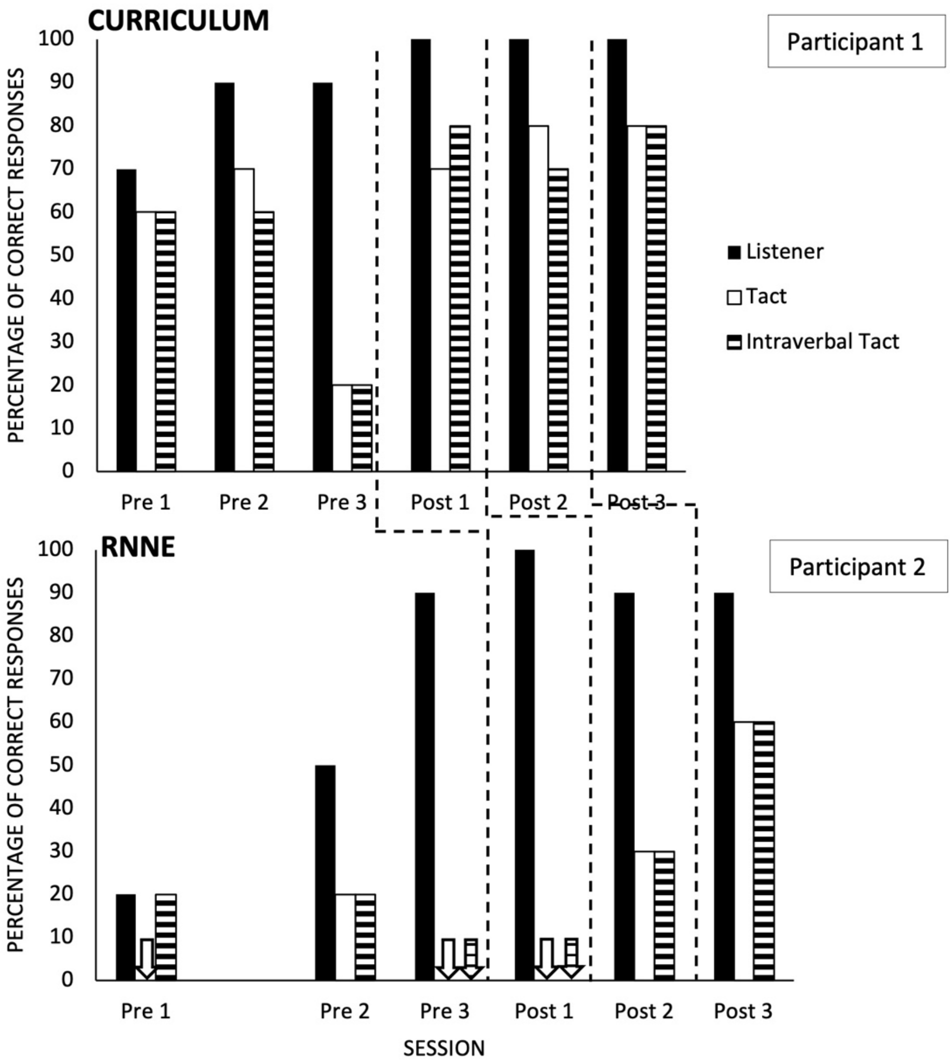


Figure 14. Pre- and post-intervention data for familiar picture word-relations across participants in Dyad 1. Participant 1 (top panel) received the curriculum-based intervention. Participant 2 (bottom panel) received the RNNE intervention. Dotted lines between probe sessions indicate intervention phases. Black bars represent percentage of correct listener responses. White bars represent the percentage of correct tact responses. Horizontal striped bars represent percentage of correct intraverbal tact responses.

Unfamiliar Picture-Word Relations. Prior to the intervention, Participant 1 (see Figure 15) emitted 70% correct listener, 60% correct tact, and 60% correct intraverbal responses, while

Participant 2 emitted 20%, 50% correct listener, 0%, 10% correct tact, and 20%, 0% correct intraverbal tact responses across two pre-intervention probes (see Figure 16).

Participant 1 demonstrated BiN for unfamiliar picture-word relations after three intervention phases. After the first phase, Participant 1 emitted 100% correct listener, 60% correct tact, and 60% correct intraverbal tact responses, while Participant 2 emitted 100% correct listener, 0% correct tact, and 0% correct intraverbal responses. Following the second intervention phase, Participant 1 emitted 90% correct listener, 20% correct tact, and 50% correct intraverbal tact responses, while Participant 2 emitted 70% correct listener, 0% correct tact, and 0% correct intraverbal responses. In the third post-intervention probe, Participant 1 demonstrated the presence of BiN, for unfamiliar picture-word relations, with 100% correct listener, 80% correct tact, and 80% correct intraverbal tact responses. Participant 2 emitted 100% correct listener, 40% correct tact, and 40% correct intraverbal tact responses in the third post-intervention probe.

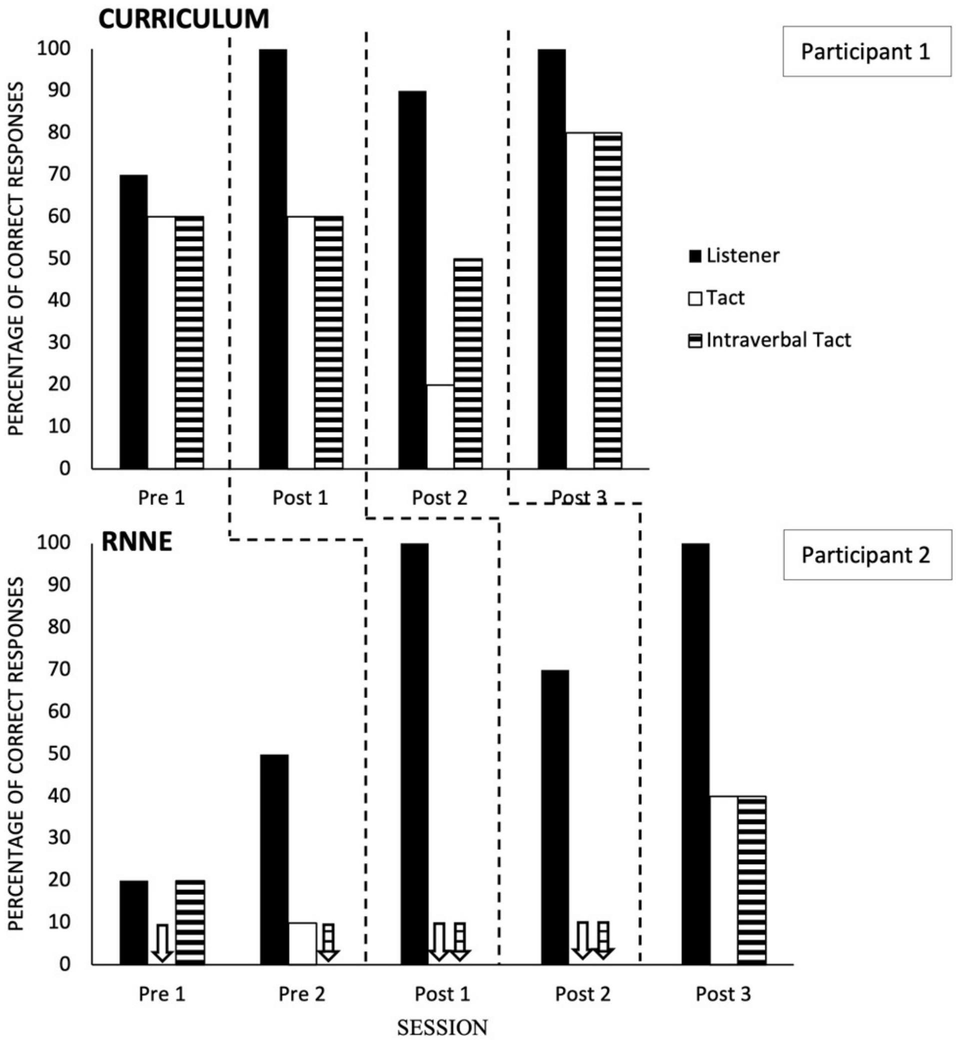


Figure 15. Pre- and post-intervention data for unfamiliar picture word-relations across participants in Dyad 1. Participant 1 (top panel) received the curriculum-based intervention. Participant 2 (bottom panel) received the RNNE intervention. Dotted lines between probe sessions indicate intervention phases. Black bars represent percentage of correct listener responses. White bars represent the percentage of correct tact responses. Horizontal striped bars represent percentage of correct intraverbal tact responses.

Learn-Units-to-Criterion (LUC)

During the intervention, Participant 1(see Figure 16) learned at a mean rate of 40 LUC (range 20-60) across three math units. Following the acquisition of BiN, Participant 1 demonstrated a mean rate of 46.7 LUC (range 20-80) across three math units. In reading, Participant 1's LUC decreased from a mean of 60 LUC (range 20-80) to 40 LUC (range 20-60) following the acquisition of BiN.

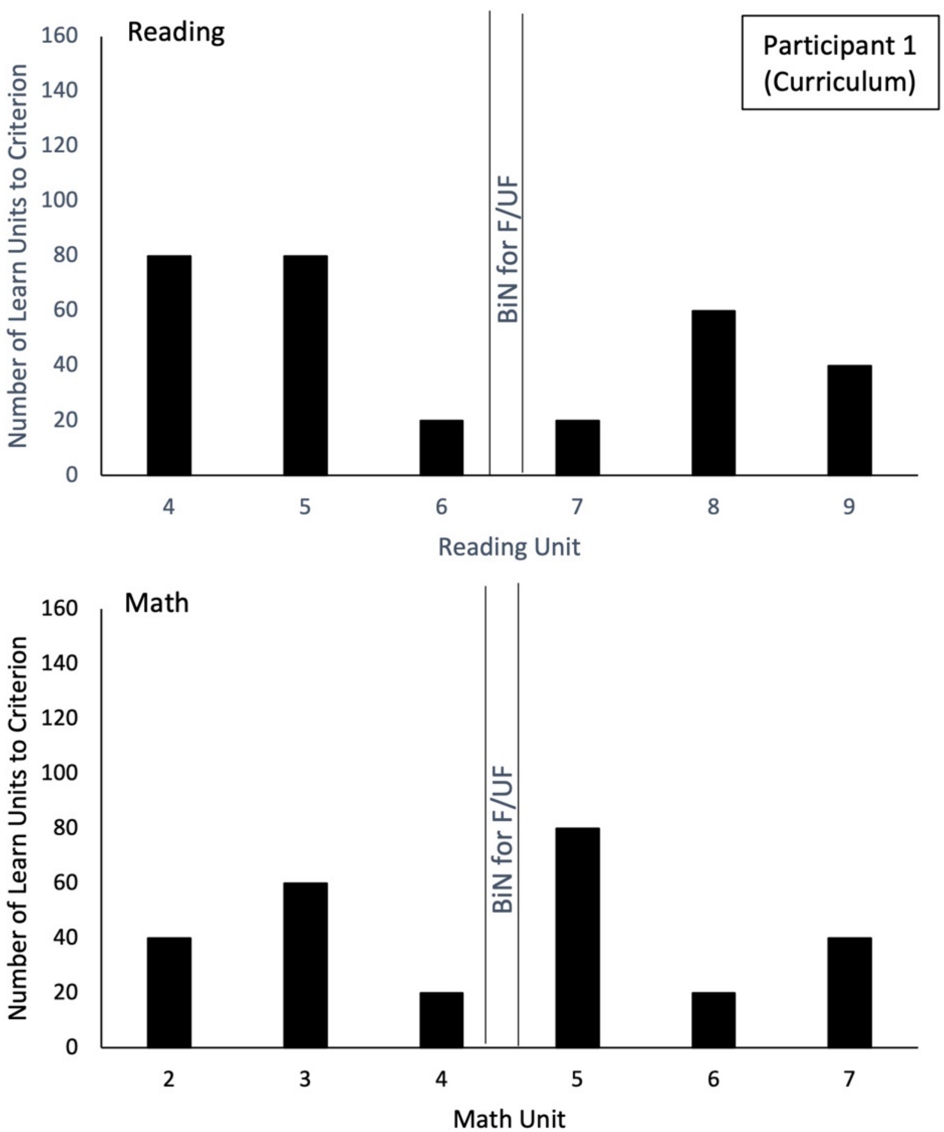


Figure 16. Number of LUC for Reading (top panel) and Math (bottom panel) pre- and post-demonstration of BiN for Participant 1.

Unconsequated Post Instruction Test

In Dyad 1, Participant 1 had a mean of 96.7% (range 90%-100%) correct responses to unconsequated post unit tests across three reading units (see Figure 17) in both pre- and post-BiN acquisition. Participant 1 demonstrated a slight increase in the mean percentage of correct responses for math unit tests (see Figure 18). Prior to the acquisition of BiN, Participant 1 had a mean accuracy of 94.3% (range 88%-100%). Following the demonstration of BiN, Participant 1 had a mean accuracy of 97.3% (range 92%-100%) across three math unit tests. Participant 2 had 100% accuracy across all pre-instruction unit tests, thus, not requiring instruction for math and reading using the current curriculum.

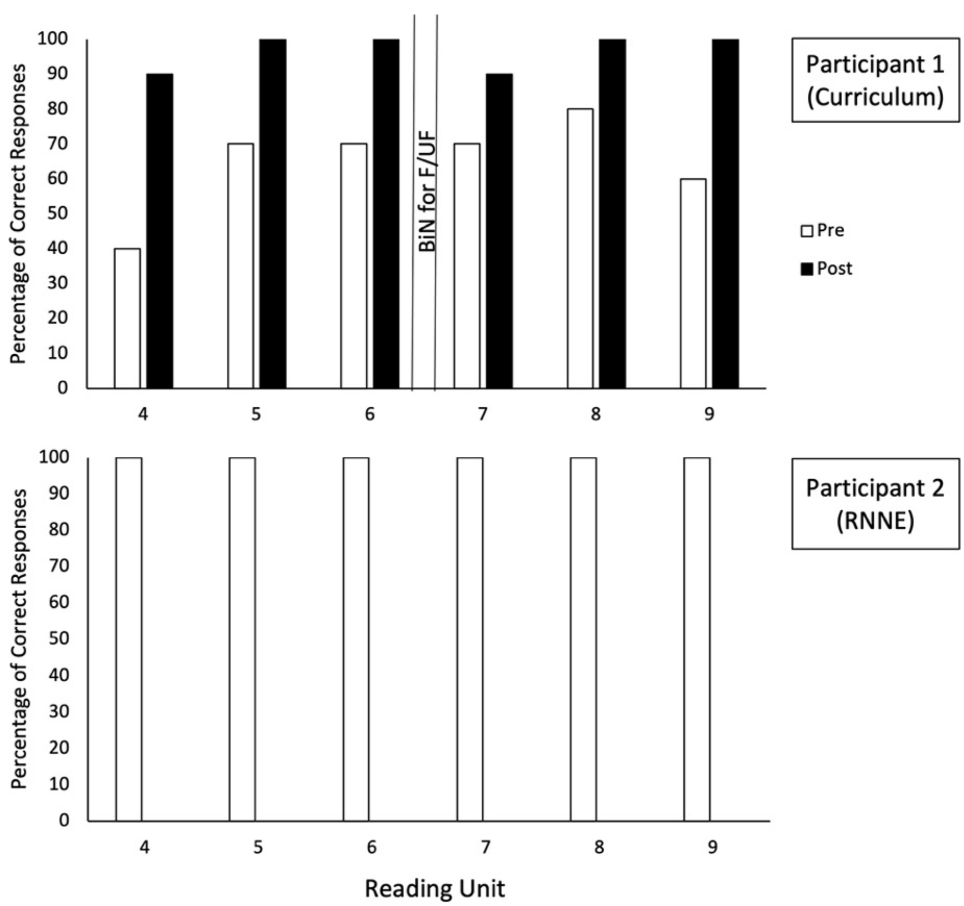


Figure 17. Unconsequated pre and post reading instruction unit tests for Participant 1 (top panel) and Participant 2 (bottom panel). White bars represent correct responses in pre-instruction unit tests. Black bars represent correct responses in the post-instruction unit tests.

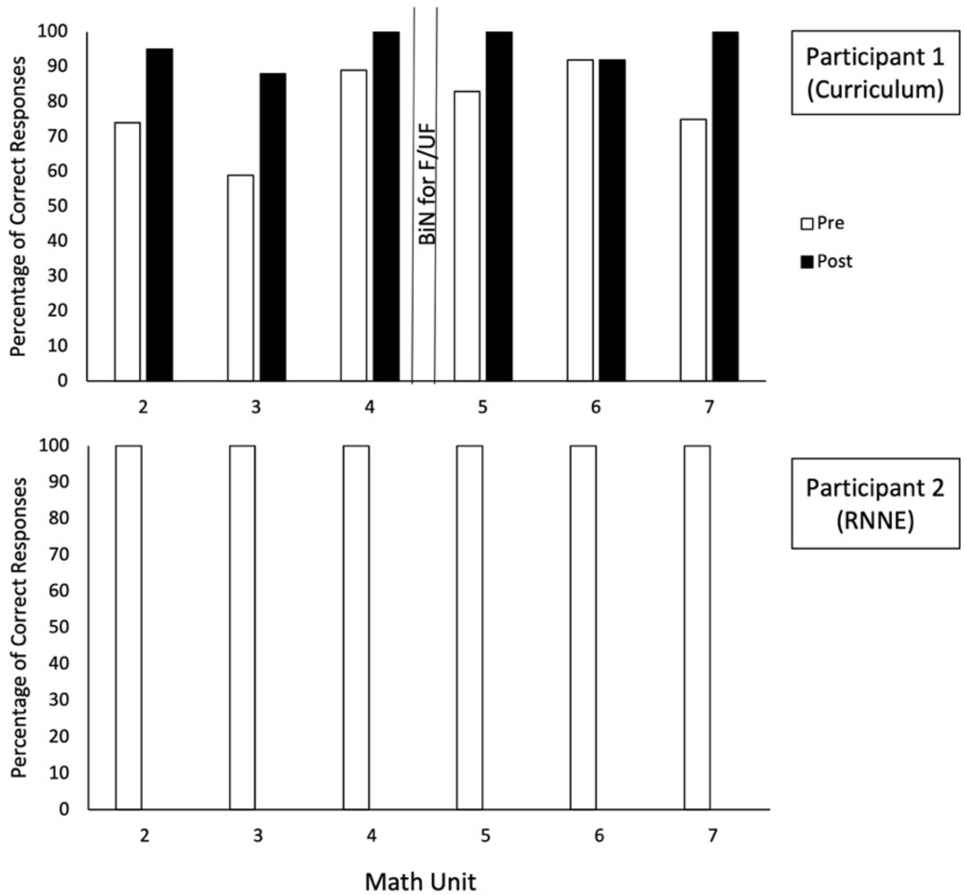
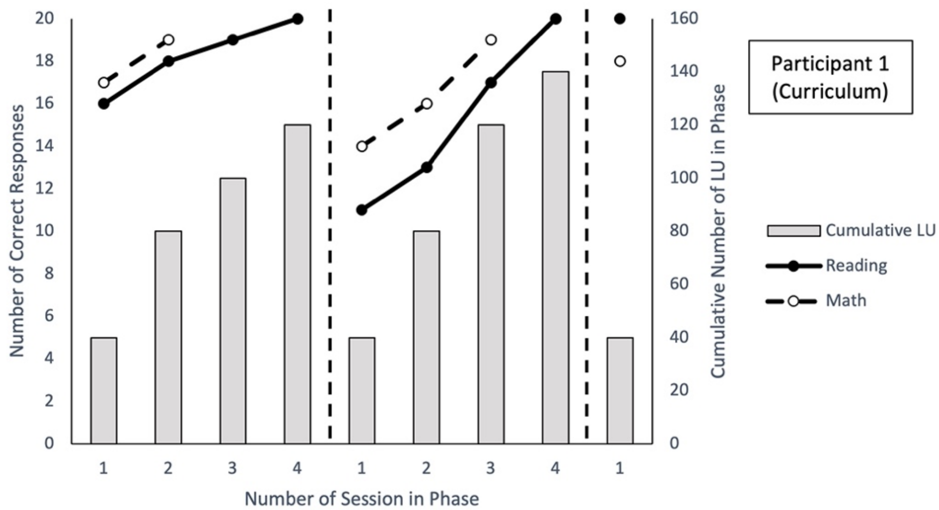


Figure 18. Unconsequated pre and post math instruction unit tests for Participant 1 (top panel) and Participant 2 (bottom panel). White bars represent correct responses in pre-instruction unit tests. Black bars represent correct responses in the post-instruction unit tests.

Intervention

In Dyad 1 (see Figure 19), Participant 1 needed a total of three intervention phases to meet criterion for demonstrating BiN for both familiar and unfamiliar picture-word relations. Participant 1 received a total of 300 academic learn units throughout the intervention while Participant 2 received a total of 320 naming experiences across eight RNNE sessions.



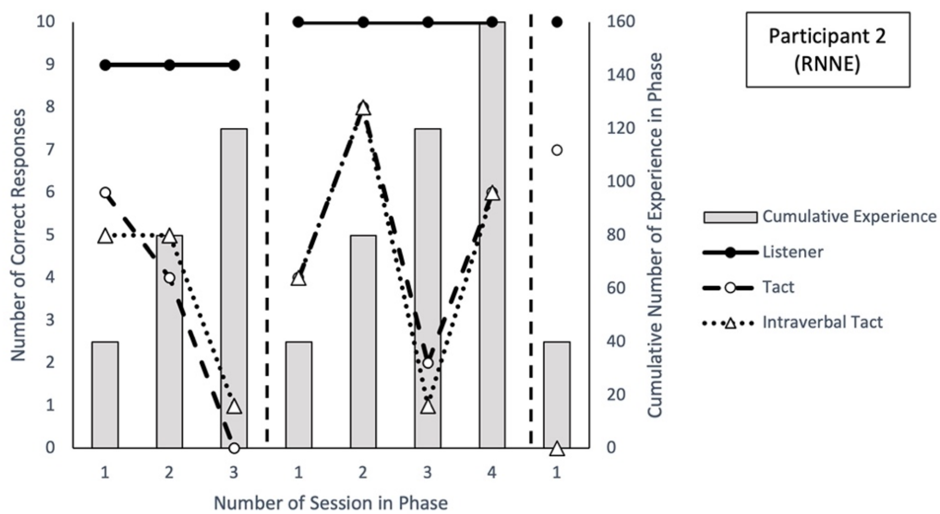


Figure 19. Intervention data for participants in Dyad 1. Participant 1's curriculum-based (top panel) and Participant 2's RNNE (bottom panel) intervention.

Dyad 2

Degree of Bidirectional Naming

Familiar Picture-Word Relations. In the pre-intervention probe, Participant 3 emitted 60% and 80% correct listener, 20% and 60% correct tact, and 10% and 60% correct intraverbal tact, while Participant 4 emitted 90% and 100% correct listener, 60% and 60% correct tact, and

60% and 40% correct intraverbal tact responses across two pre-intervention probes (see Figure 20).

In Dyad 2 (see Figure 20), Participant 3 demonstrated BiN for familiar picture-word relations after one intervention phase. After the first phase, Participant 1 emitted 90% correct listener, 100% correct tact, and 80% correct intraverbal tact responses, demonstrating the presence of BiN for familiar picture-word relations. In the first post-intervention probe, Participant 4 emitted 100% correct listener, 40% correct tact, and 40% correct intraverbal responses. Following the second intervention phase, Participant 3 emitted 100% correct listener, 80% correct tact, and 80% correct intraverbal tact responses, while Participant 4 emitted 100% correct listener, 40% correct tact, and 20% correct intraverbal responses. In the third post-intervention probe, Participant 3 emitted 100% correct listener, 80% correct tact, and 80% correct intraverbal tact responses, while Participant 4 emitted 100% correct listener, 80% correct tact, and 80% correct intraverbal tact responses. Both participants in Dyad 2 demonstrated BiN for familiar picture-word relations level of complexity.

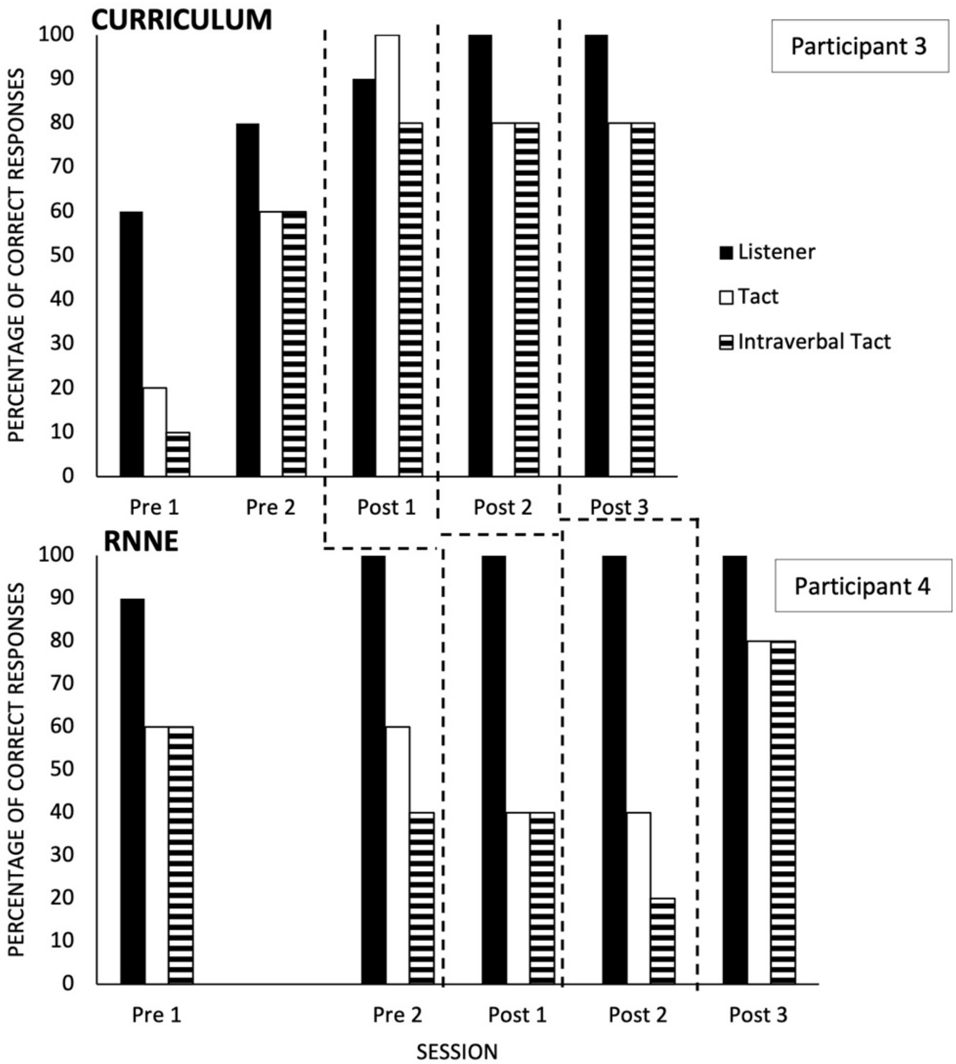


Figure 20. Pre- and post-intervention data for familiar picture word-relations across participants in Dyad 2. Participant 3 (top panel) received the curriculum-based intervention. Participant 4 (bottom panel) received the RNNE intervention. Dotted lines between probe sessions indicate intervention phases. Black bars represent percentage of correct listener responses. White bars represent the percentage of correct tact responses. Horizontal striped bars represent percentage of correct intraverbal tact responses.

Unfamiliar Picture-Word Relations. Participant 3 emitted 60% and 80% correct listener, 20% and 60% correct tact, and 10% and 60% correct intraverbal tact, while Participant 4 emitted 70% and 100% correct listener, 0% and 60% correct tact, and 10% and 60% correct intraverbal tact responses across two pre-intervention probes.

In Dyad 2 (see Figure 21), Participant 3 demonstrated BiN for unfamiliar picture-word relations after two intervention phases. In the first post-intervention probe, Participant 3 emitted 80% correct listener, 60% correct tact, and 60% correct intraverbal tact responses, while Participant 4 emitted 80% correct listener, 20% correct tact, and 10% correct intraverbal tact responses. Following the second intervention phase, Participant 3 emitted 90% correct listener, 100% correct tact, and 80% correct intraverbal tact responses, demonstrating the presence of BiN for unfamiliar picture-word relations level of complexity. In the second post-intervention probe, Participant 4 emitted 70% correct listener, 10% correct tact, and 0% correct intraverbal tact responses. In the third post-intervention probe, Participant 3 emitted 100% correct listener, 80% correct tact, and 80% correct intraverbal tact responses, while Participant 4 emitted 100% correct listener, 40% correct tact, and 40% correct intraverbal tact responses.

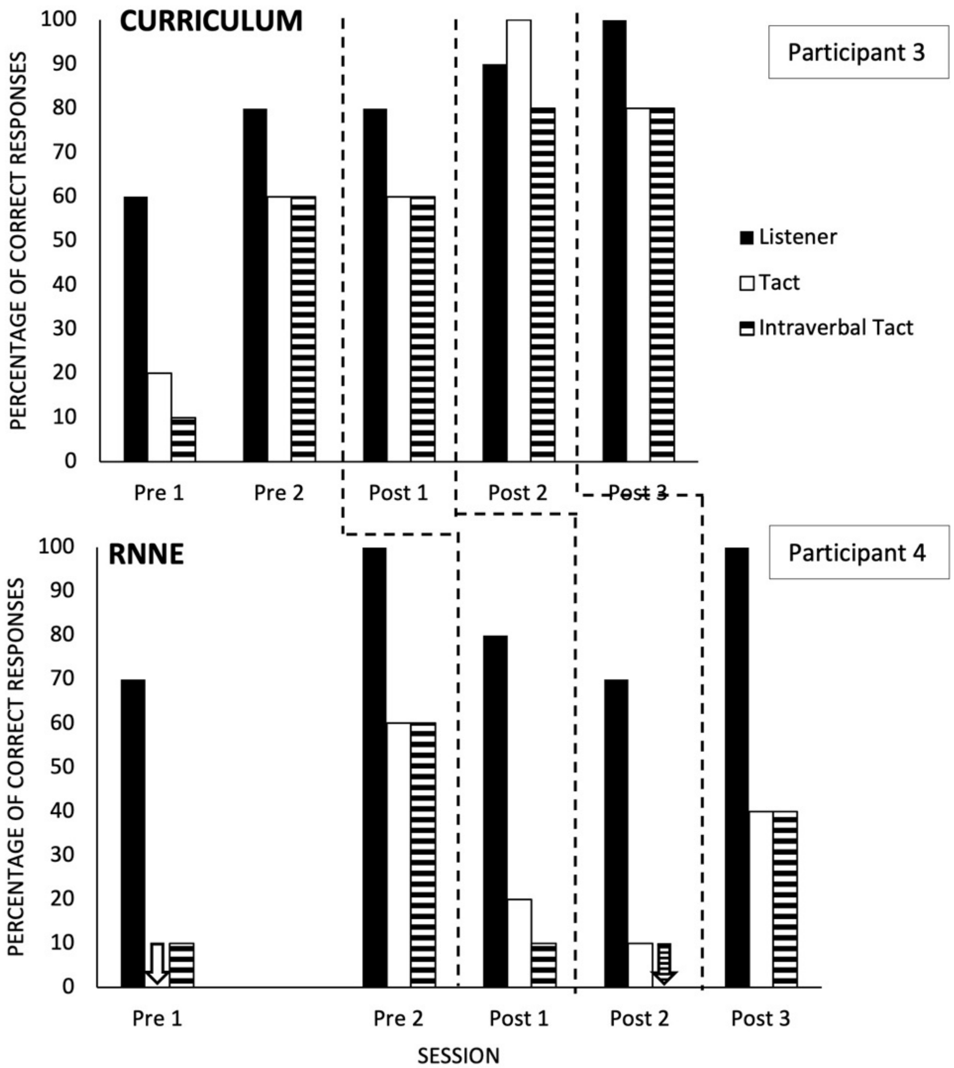


Figure 21. Pre- and post-intervention data for unfamiliar picture word-relations across participants in Dyad 2. Participant 3 (top panel) received the curriculum-based intervention. Participant 4 (bottom panel) received the RNNE intervention. Dotted lines between probe sessions indicate intervention phases. Black bars represent percentage of correct listener responses. White bars represent the percentage of correct tact responses. Horizontal striped bars represent percentage of correct intraverbal tact responses.

Learn-Units-to-Criterion (LUC)

In Dyad 2, Participant 3 (see Figure 22) learned at a mean rate of 60 LUC (range 20-80) across three math units. Following the acquisition of BiN, Participant 4 (see Figure 23) learned at a mean rate of 46.7 LUC (range 20-60) across three math units. In reading, Participant 2's LUC increased from a mean of 60 LUC (range 40-80) to 66.7 LUC (range 60-80) following the acquisition of BiN. Participant 4 acquired BiN for familiar picture-word relations following the RNNE intervention. Prior to the intervention, Participant 4 required 60 learn units to meet one math criterion and 80 learn units to meet one reading criterion. Following the demonstration of BiN, Participant 4 learned math at a mean rate of 48 LUC (range 40-60) and reading at a mean rate of 52 LUC (range 40-60).

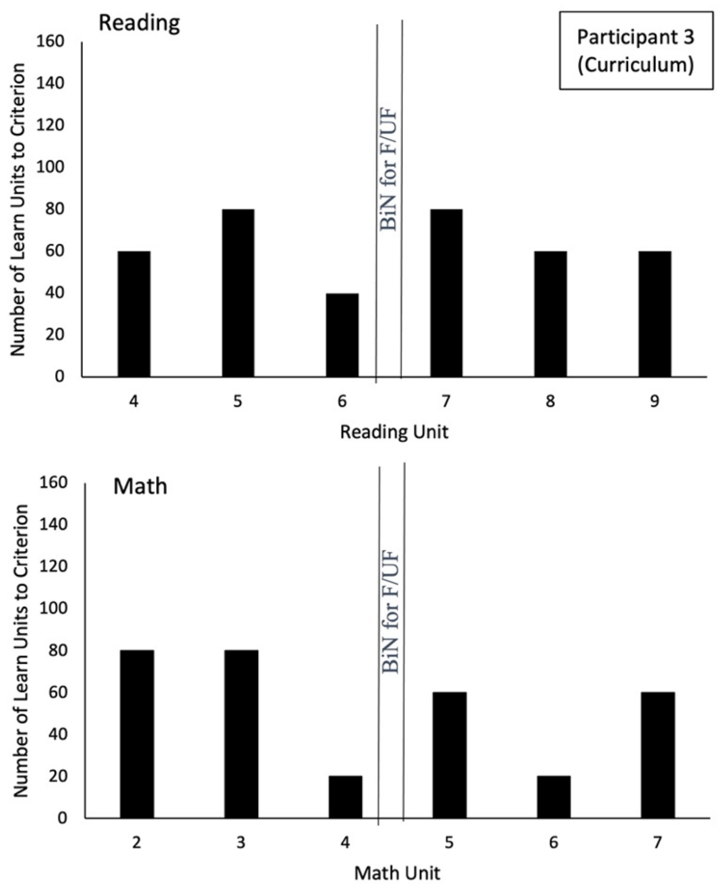


Figure 22. Number of LUC for Reading (top panel) and Math (bottom panel) pre- and post-demonstration of BiN for Participant 3.

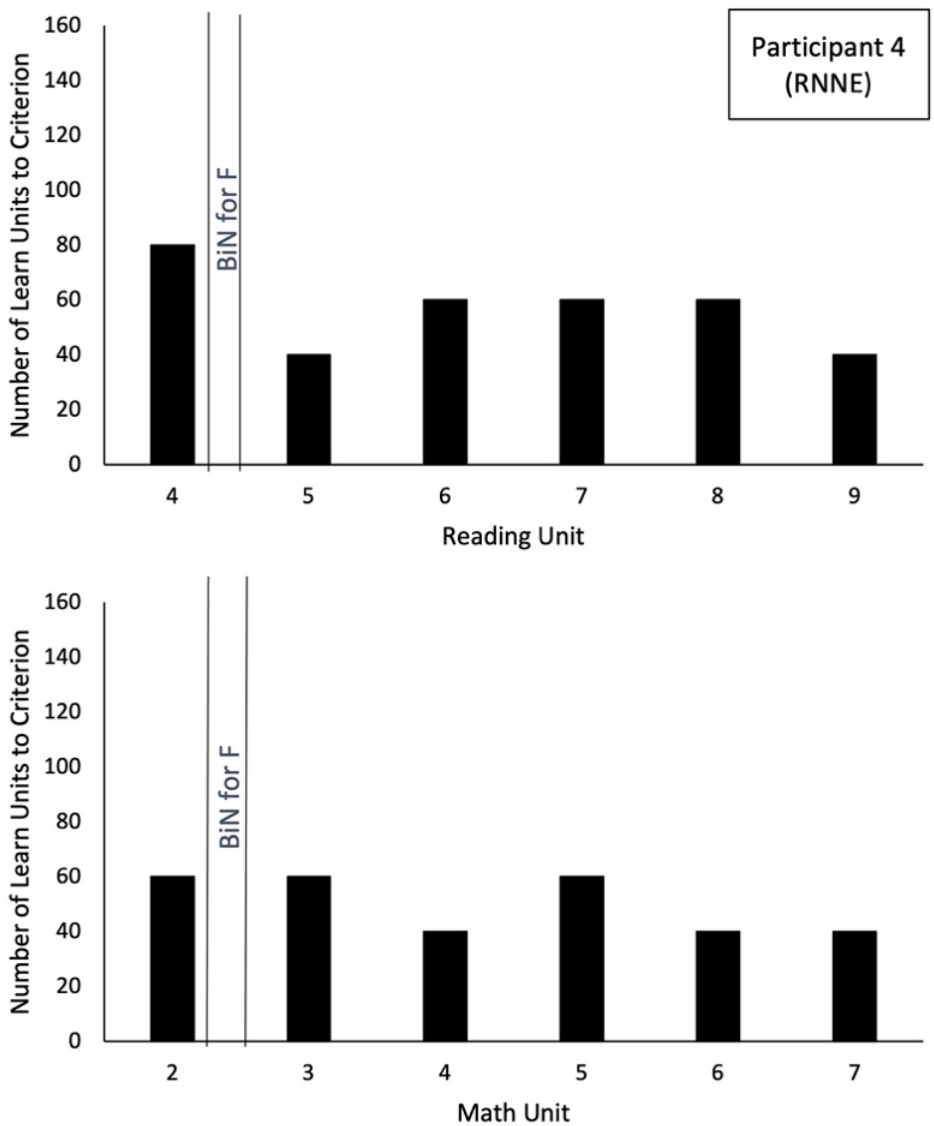


Figure 23. Number of LUC for Reading (top panel) and Math (bottom panel) pre- and post-demonstration of BiN for Participant 4.

Unconsequated Post Instruction Test

In Dyad 2, Participant 3 had a mean of 90% (range 90%-90%) correct responses to unconsequated post unit tests across three reading units (see Figure 24) prior to demonstrating

BiN. In the post-BiN acquisition unit tests, Participant 3 had a mean of 96.7% (range 90%-100%) accuracy across three reading post-unit tests. In math (see Figure 25), Participant 3 demonstrated a mean of 96.3% (range 89%-100%) accuracy across three math unit posttests, prior to demonstrating BiN. Following the demonstration of BiN, Participant 3 had a mean of 97.3% (range 92%-100%) accuracy across three post-unit tests. Prior to the acquisition of BiN, Participant 4 demonstrated 89% accuracy to an unconsequated math post-unit test. Following the intervention, Participant 4 had a mean of 93.8% (range 83%-100%) accuracy in post-unit math tests across five tests. In the pre-intervention reading post-test, Participant 4 emitted 90% accuracy in one reading post-unit test. Following the acquisition of BiN, Participant 4 demonstrated a mean of 90% (range 80%-100%) accuracy across five unconsequated post reading unit tests.

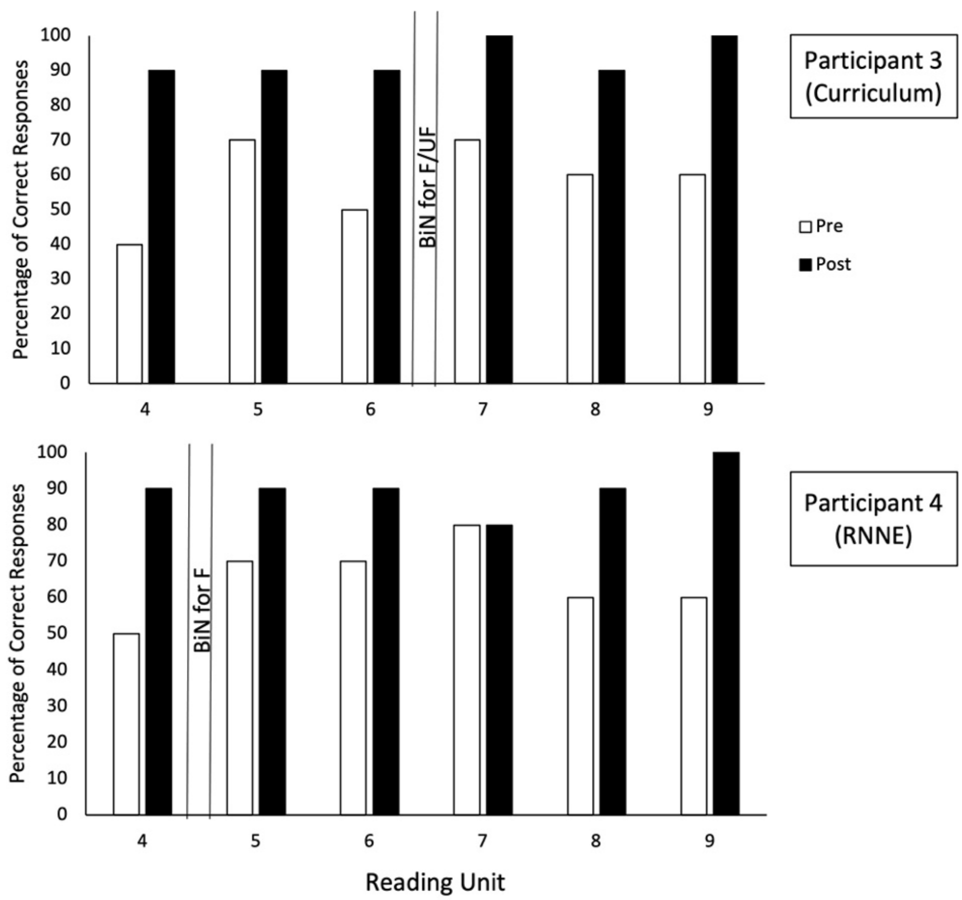


Figure 24. Unconsequated pre and post reading instruction unit tests for Participant 3 (top panel) and Participant 4 (bottom panel). White bars represent correct responses in pre-instruction unit tests. Black bars represent correct responses in the post-instruction unit tests.

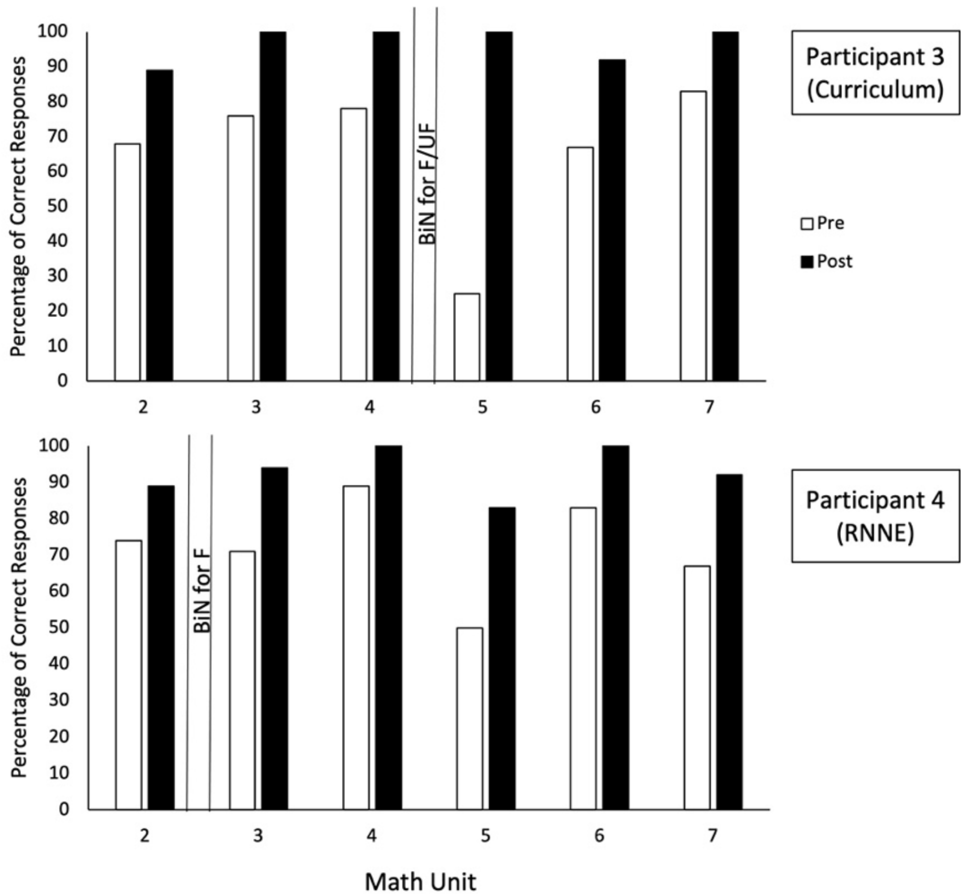


Figure 25. Unconsequated pre and post math instruction unit tests for Participant 3 (top panel) and Participant 4 (bottom panel). White bars represent correct responses in pre-instruction unit tests. Black bars represent correct responses in the post-instruction unit tests.

Intervention

In Dyad 2 (see Figure 26), Participant 3 received a total of 360 academic learn units throughout the intervention. Participant 3 demonstrated the presence of BiN across both levels of complexity after two phases of interventions (or 300 academic learn units). Participant 4 received a total of 400 naming experiences but did not meet criterion for demonstration of BiN.

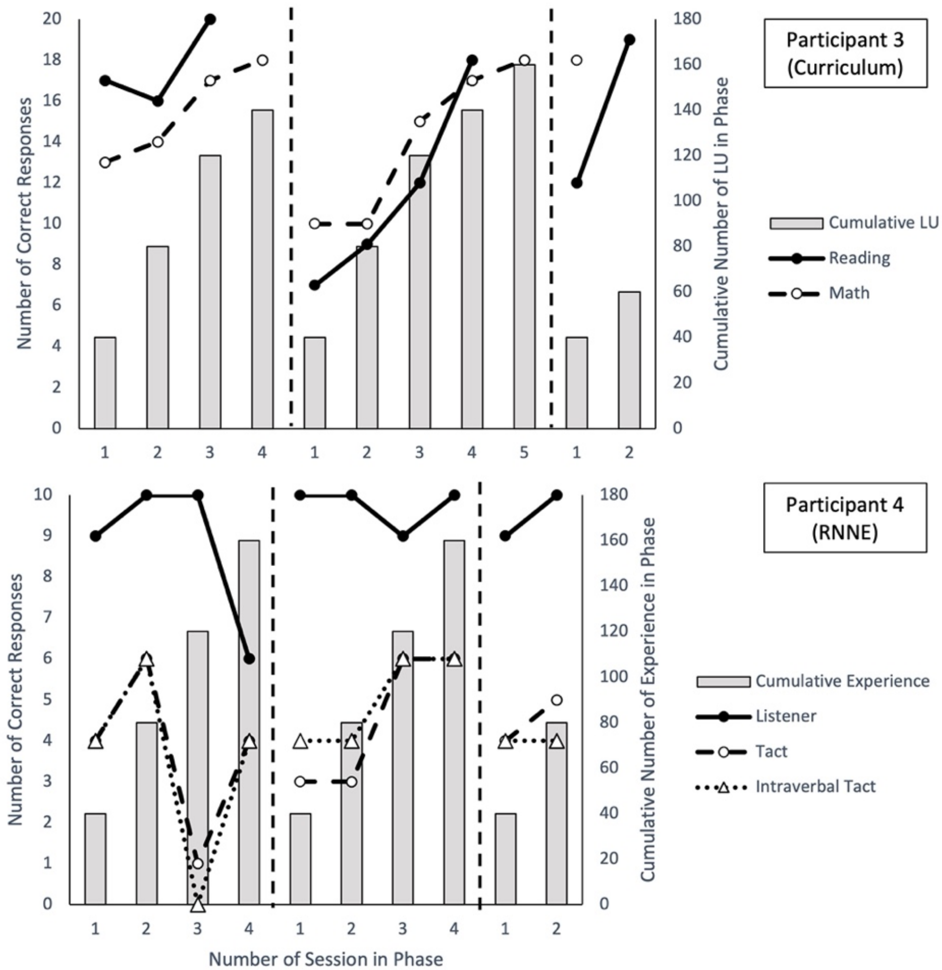


Figure 26. Intervention data for participants in Dyad 2. Participant 3's curriculum-based (top panel) and Participant 4's RNNE (bottom panel) intervention.

Dyad 3

Degree of Bidirectional Naming

Familiar Picture-Word Relations. Prior to the intervention, Participant 5 emitted 50%, 60%, 80% correct listener, 40%, 0%, 20% correct tact, and 40%, 0%, 10% correct intraverbal tact responses, while Participant 6 emitted 80%, 70%, 80% correct listener, 40%, 0%, 20% correct tact, and 40%, 10%, 20% correct intraverbal tact responses across three pre-intervention probes (see Figure 27).

Participant 5 demonstrated BiN for familiar picture-word relations after six intervention phases. After the first phase, Participant 5 emitted 90% correct listener, 0% correct tact, and 30% correct intraverbal tact responses, while Participant 6 emitted 100% correct listener, 40% correct tact, and 60% correct intraverbal responses. Following the second intervention phase, Participant 5 emitted 80% correct listener, 20% correct tact, and 20% correct intraverbal tact responses, while Participant 6 emitted 70% correct listener, 20% correct tact, and 10% correct intraverbal responses. In the third post-intervention probe, Participant 5 emitted 100% correct listener, 70% correct tact, and 60% correct intraverbal tact responses, while Participant 6 emitted 80% correct listener, 20% correct tact, and 0% correct intraverbal tact responses. Following the fourth intervention phase, Participant 5 emitted 90% correct listener, 60% correct tact, and 60% correct intraverbal tact, while Participant 6 emitted 80% correct listener, 30% correct tact, and 0% correct intraverbal tact responses. In the fifth post-intervention probe, Participant 5 emitted 100% correct listener, 70% correct tact, and 80% correct intraverbal tact responses, while Participant 6 emitted 80% correct listener, 20% correct tact, and 20% correct intraverbal tact responses. Following the sixth intervention phase, Participant 5 emitted 100% correct listener, 80% correct tact, and 80% correct intraverbal responses, demonstrating the presence of BiN for familiar picture-word relations level of complexity. In the sixth post-intervention probe, Participant 6 emitted 80% correct listener, 0% correct speaker, and 0% correct intraverbal tact responses.

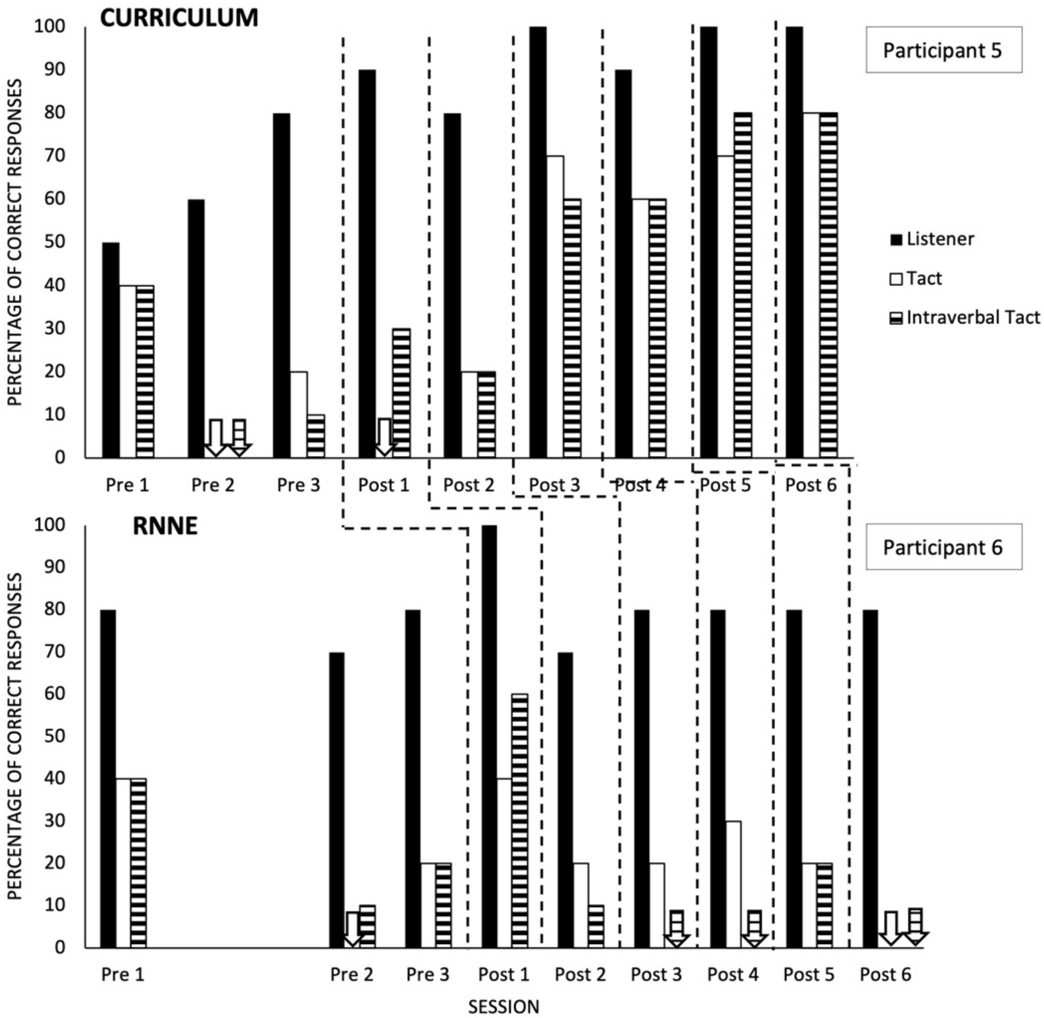


Figure 27. Pre- and post-intervention data for familiar picture word-relations across participants in Dyad 3. Participant 5 (top panel) received the curriculum-based intervention. Participant 6 (bottom panel) received the RNNE intervention. Dotted lines between probe sessions indicate intervention phases. Black bars represent percentage of correct listener responses. White bars represent the percentage of correct tact responses. Horizontal striped bars represent percentage of correct intraverbal tact responses.

Unfamiliar Picture-Word Relations. Prior to the intervention, Participant 5 emitted 40%, 90% correct listener, 20%, 40% correct tact, and 0%, 50% correct intraverbal tact responses, while Participant 6 emitted 50%, 100% correct listener, 20%, 20% correct tact, and 20%, 20% correct intraverbal tact responses across two pre-intervention probes (see Figure 28).

In Dyad 3 (see Figure 28), Participant 5 emitted 80% correct listener, 20% correct tact, and 0% correct intraverbal tact responses, while Participant 6 emitted 50% correct listener, 10% correct tact, and 10% correct intraverbal responses, in the first post-intervention probe. Following the second intervention phase, Participant 5 emitted 80% correct listener, 20% correct tact, and 20% correct intraverbal tact responses, while Participant 6 emitted 50% correct listener, 20% correct tact, and 0% correct intraverbal responses. In the third post-intervention probe, Participant 5 emitted 80% correct listener, 40% correct tact, and 40% correct intraverbal tact responses, while Participant 6 emitted 10% correct listener, 0% correct tact, and 0% correct intraverbal tact responses. Following the fourth intervention phase, Participant 5 emitted 100% correct listener, 60% correct tact, and 50% correct intraverbal tact, while Participant 6 emitted 90% correct listener, 20% correct tact, and 20% correct intraverbal tact responses. In the fifth post-intervention probe, Participant 5 emitted 100% correct listener, 60% correct tact, and 60% correct intraverbal tact responses, while Participant 6 emitted 80% correct listener, 0% correct tact, and 0% correct intraverbal tact responses. Following the sixth intervention phase, Participant 5 emitted 100% correct listener, 60% correct tact, and 60% correct intraverbal responses, while Participant 6 emitted 70% correct listener, 0% correct speaker, and 0% correct intraverbal tact responses.

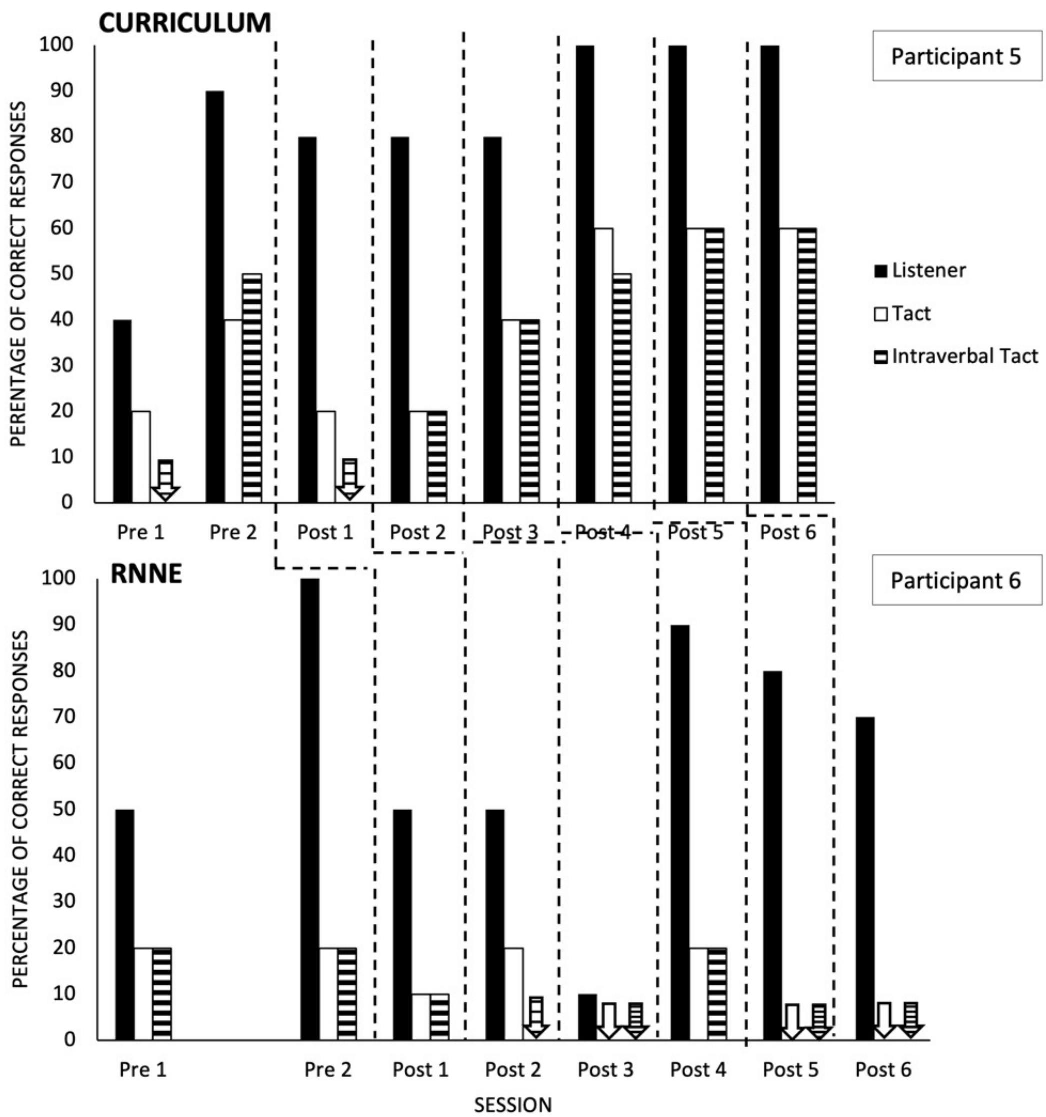


Figure 28. Pre- and post-intervention data for unfamiliar picture word-relations across participants in Dyad 3. Participant 5 (top panel) received the curriculum-based intervention. Participant 6 (bottom panel) received the RNNE intervention. Dotted lines between probe sessions indicate intervention phases. Black bars represent percentage of correct listener responses. White bars represent the percentage of correct tact responses. Horizontal striped bars represent percentage of correct intraverbal tact responses.

Learn-Units-to-Criterion (LUC)

Participant 5 (see Figure 29) demonstrated a mean rate of 60 LUC (range 40-80) for math and 70 LUC (range 20-120) for reading instruction across six units during the intervention. Following the acquisition of BiN, Participant 5 demonstrated 40 LUC for math and 40 LUC for reading for one unit per subject. Participant 7 (see Figure 30) demonstrated a mean rate of 76 LUC (range 40-140) for math and 132 LUC (range 120-160) for reading across five units.

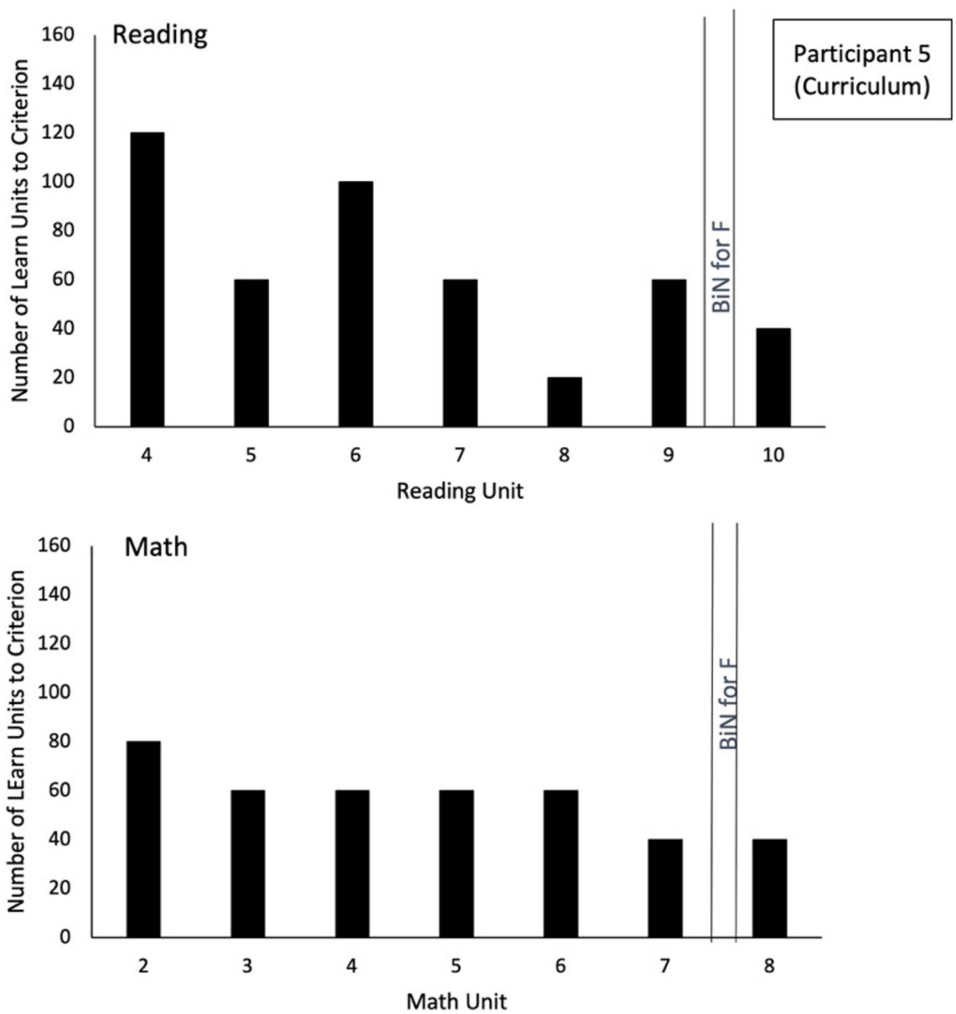


Figure 29. Number of LUC for Reading (top panel) and Math (bottom panel) pre- and post-demonstration of BiN for Participant 5.

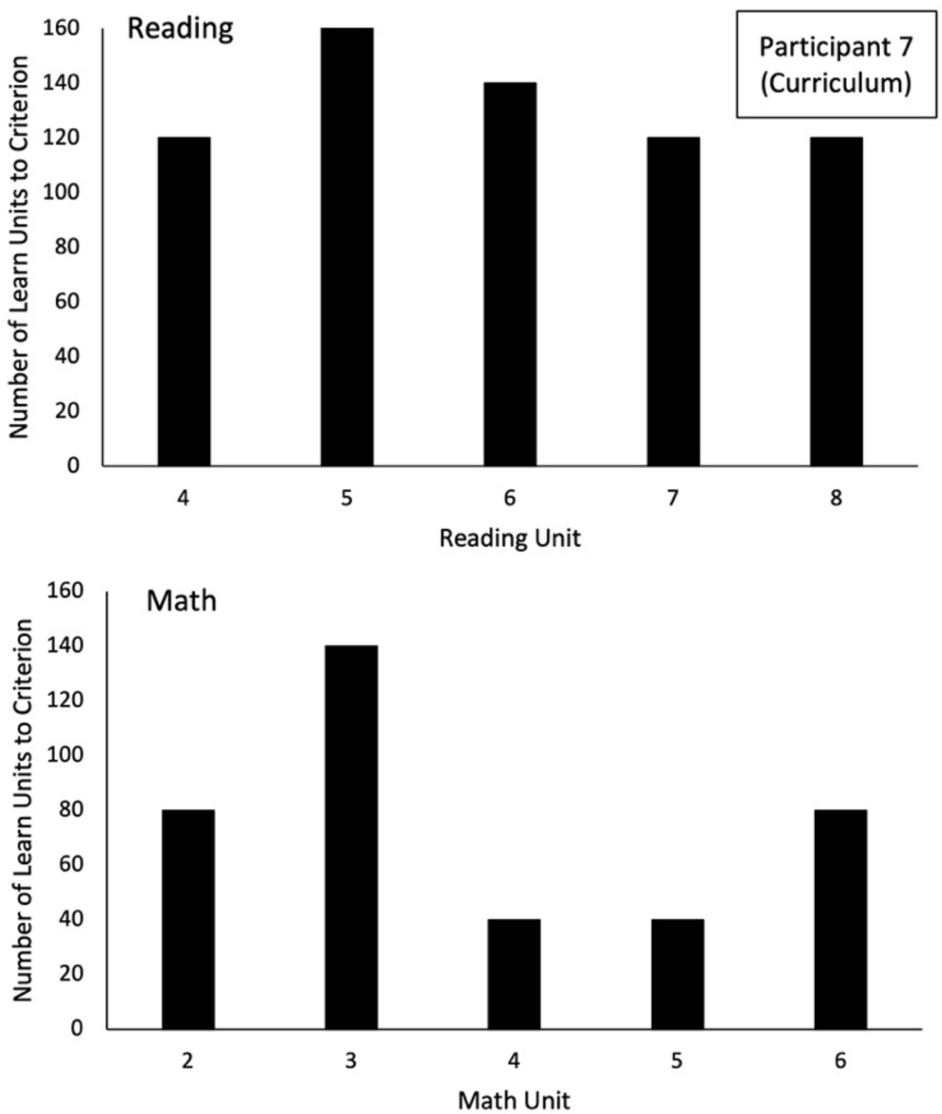


Figure 30. Number of LUC for Reading (top panel) and Math (bottom panel) pre- and post-demonstration of BiN for Participant 7.

Unconsequated Post Instruction Test

For reading post-unit tests, Participant 5 (see Figure 31) had a mean of 90% (range 80%-100%) accuracy during the intervention across six units. Following the acquisition of BiN for familiar picture-word relations, Participant 5 emitted 100% accuracy to one reading unit test. Participant 5 (see Figure 31) had a mean of 96.3% (range 92%-100%) accuracy for unconsequated post math unit tests during the intervention. Following the demonstration of BiN, Participant 5 emitted 83% accuracy in one math post-unit test.

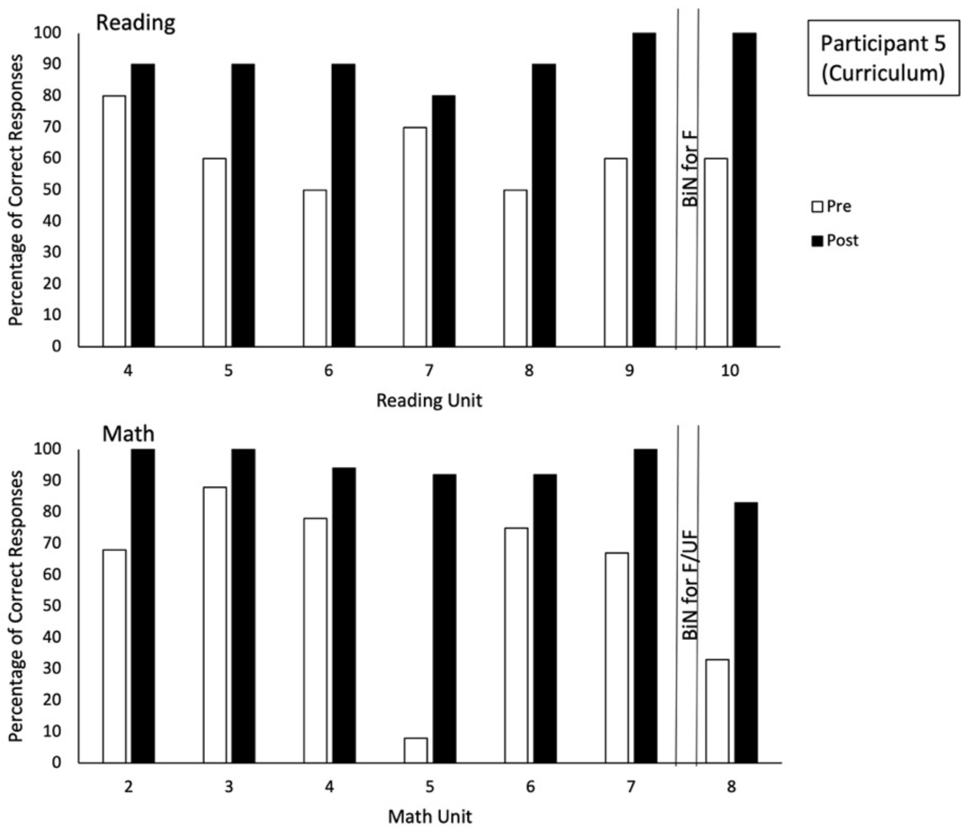


Figure 31. Unconsequated pre and post reading (top panel) and math (bottom panel) unit tests for Participant 5. White bars represent correct responses in pre-instruction unit tests. Black bars represent correct responses in the post-instruction unit tests.

Intervention

In Dyad 3 (see Figure 32), Participant 5 required a total of six intervention phases to meet criterion for demonstrating BiN for familiar picture-word relations. Participant 5 received a total of 780 academic learn units throughout the intervention while Participant 6 received a total of 800 naming experiences across 20 RNNE sessions.

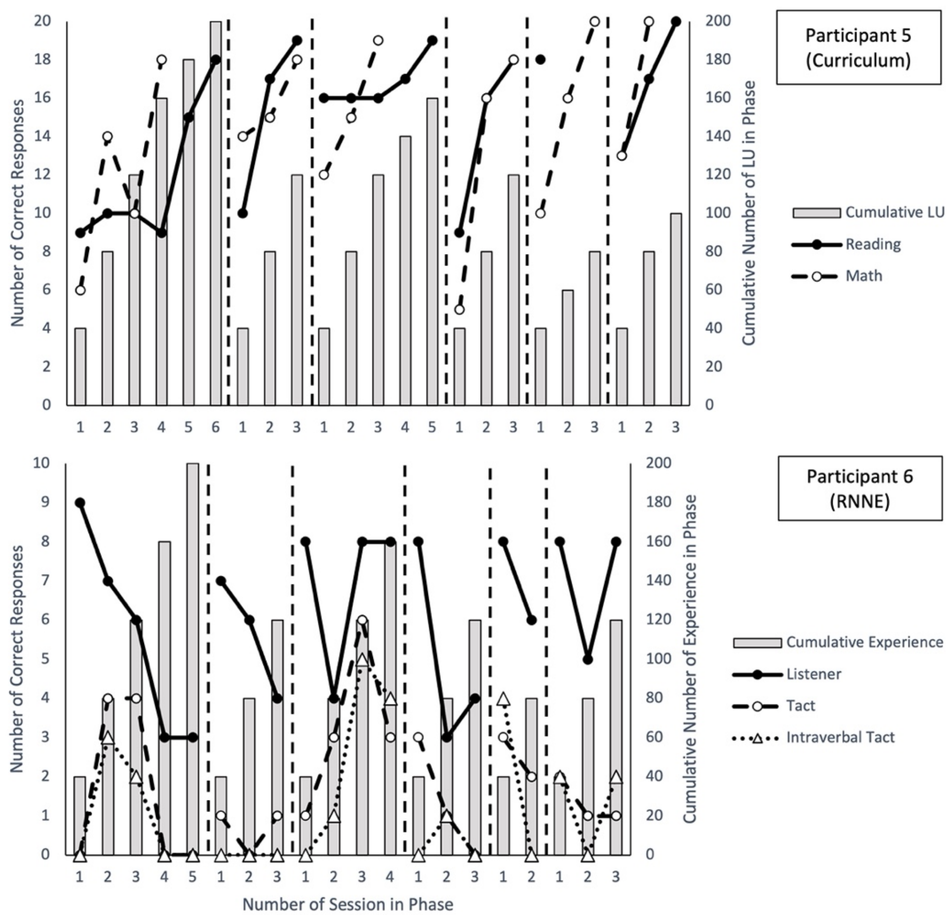


Figure 32. Intervention data for participants in Dyad 3. Participant 5's curriculum-based (top panel) and Participant 6's RNNE (bottom panel) intervention.

Dyad 4

Degree of Bidirectional Naming

Familiar Picture-Word Relations. Participant 7 emitted 40%, 80%, 80% correct listener, 0%, 50%, 0% correct tact, and 20%, 0%, 0% correct intraverbal tact responses across three pre-intervention probes. Participant 8 emitted 50%, 70%, 80%, 80% correct listener, 60%, 40%, 40%, 40% correct tact, and 40%, 40%, 40%, 0% correct intraverbal tact responses across four pre-intervention probes (see Figure 33).

Participant 7 emitted 80% correct listener, 60% correct tact, and 50% correct intraverbal tact responses, while Participant 8 emitted 30% correct listener, 60% correct tact, and 30% correct intraverbal tact responses in the first post-intervention probe. Following the second intervention phase, Participant 7 emitted 60% correct listener, 10% correct tact, and 10% correct intraverbal tact responses, while Participant 8 emitted 40% correct listener, 10% correct tact, and 0% correct intraverbal tact responses. Participant 7 emitted 60%, 80%, 80% correct listener, 30%, 30%, 10% correct tact, and 20%, 30%, 0% correct intraverbal tact responses in the subsequent post-intervention probes.

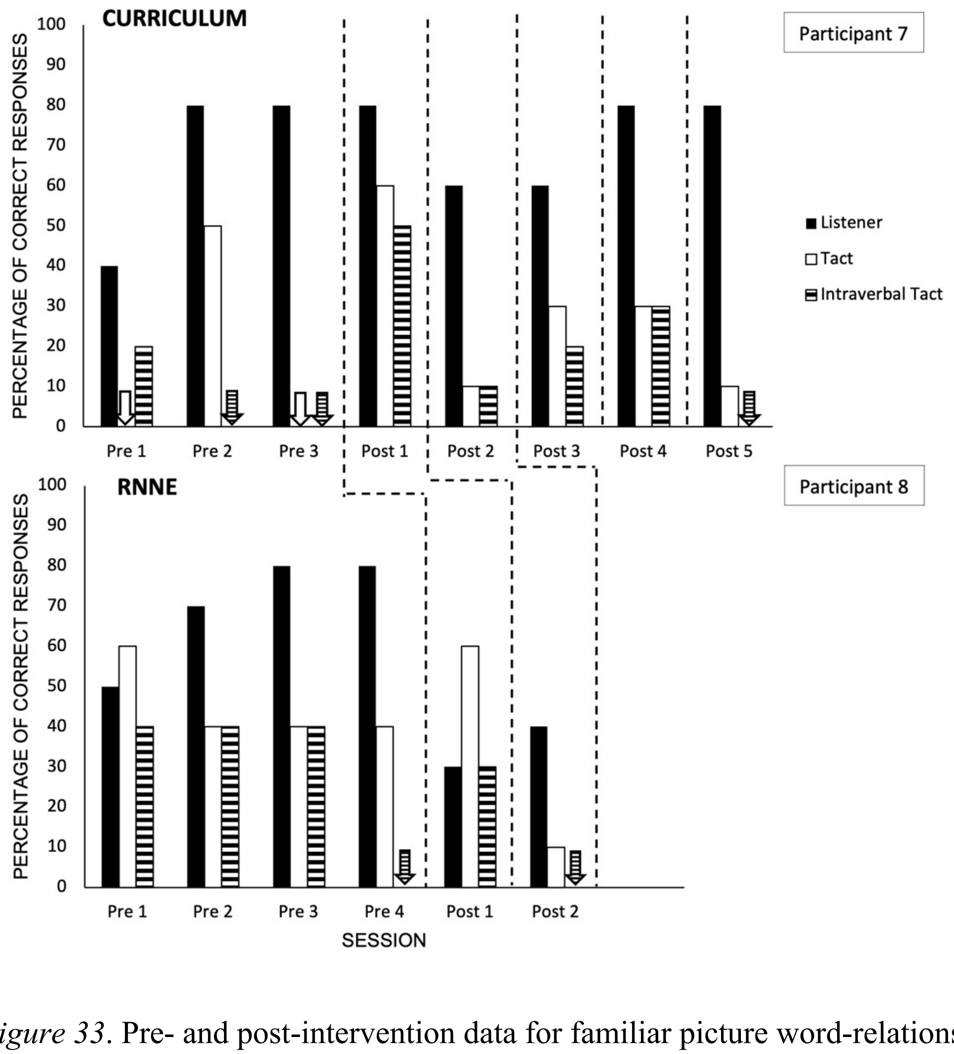


Figure 33. Pre- and post-intervention data for familiar picture word-relations across participants in Dyad 4. Participant 7 (top panel) received the curriculum-based intervention. Participant 8

(bottom panel) received the RNNE intervention. Dotted lines between probe sessions indicate intervention phases. Black bars represent percentage of correct listener responses. White bars represent the percentage of correct tact responses. Horizontal striped bars represent percentage of correct intraverbal tact responses.

Unfamiliar Picture-Word Relations. In Dyad 4 (see Figure 34), Participant 7 emitted 40% and 50% correct listener, 0% and 20% correct tact, and 20% and 20% correct intraverbal tact responses across two pre-intervention probes. Participant 8 emitted 70%, 80%, 60% correct listener, 40%, 60%, 0% correct tact, and 40%, 60%, 10% correct intraverbal tact responses across three pre-intervention probes.

Participant 7 emitted 70% correct listener, 20% correct tact, and 10% correct intraverbal tact responses, while Participant 8 emitted 60% correct listener, 10% correct tact, and 10% correct intraverbal tact responses in the first post-intervention probe. Following the second intervention phase, Participant 7 emitted 90% correct listener, 20% correct tact, and 20% correct intraverbal tact responses, while Participant 8 emitted 40% correct listener, 20% correct tact, and 20% correct intraverbal tact responses. Participant 7 emitted 80% correct listener, 20% correct tact, and 20% correct intraverbal tact responses in the following three post-intervention probes.

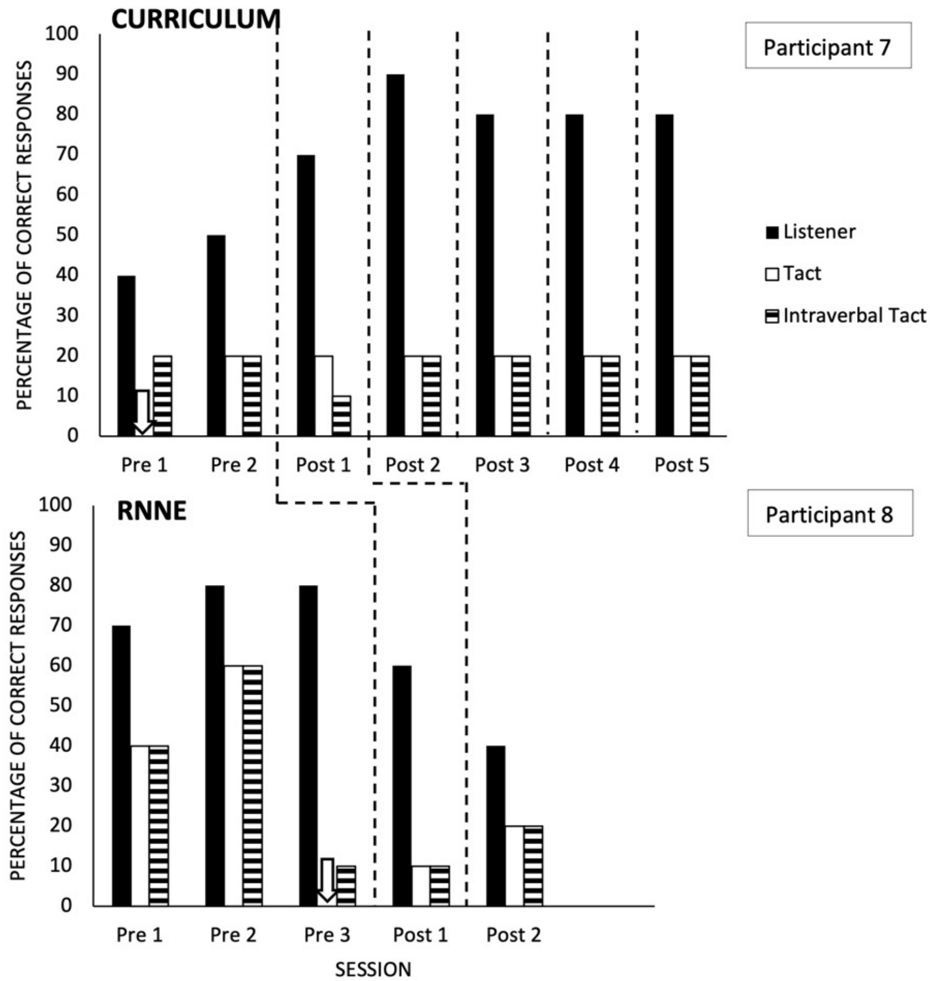


Figure 34. Pre- and post-intervention data for unfamiliar picture word-relations across participants in Dyad 4. Participant 7 (top panel) received the curriculum-based intervention. Participant 8 (bottom panel) received the RNNE intervention. Dotted lines between probe sessions indicate intervention phases. Black bars represent percentage of correct listener responses. White bars represent the percentage of correct tact responses. Horizontal striped bars represent percentage of correct intraverbal tact responses.

Learn-Units-to-Criterion (LUC)

Participant 7 (see Figure 35) demonstrated a mean rate of 76 LUC (range 40-140) for math and 132 LUC (range 120-160) for reading across five units.

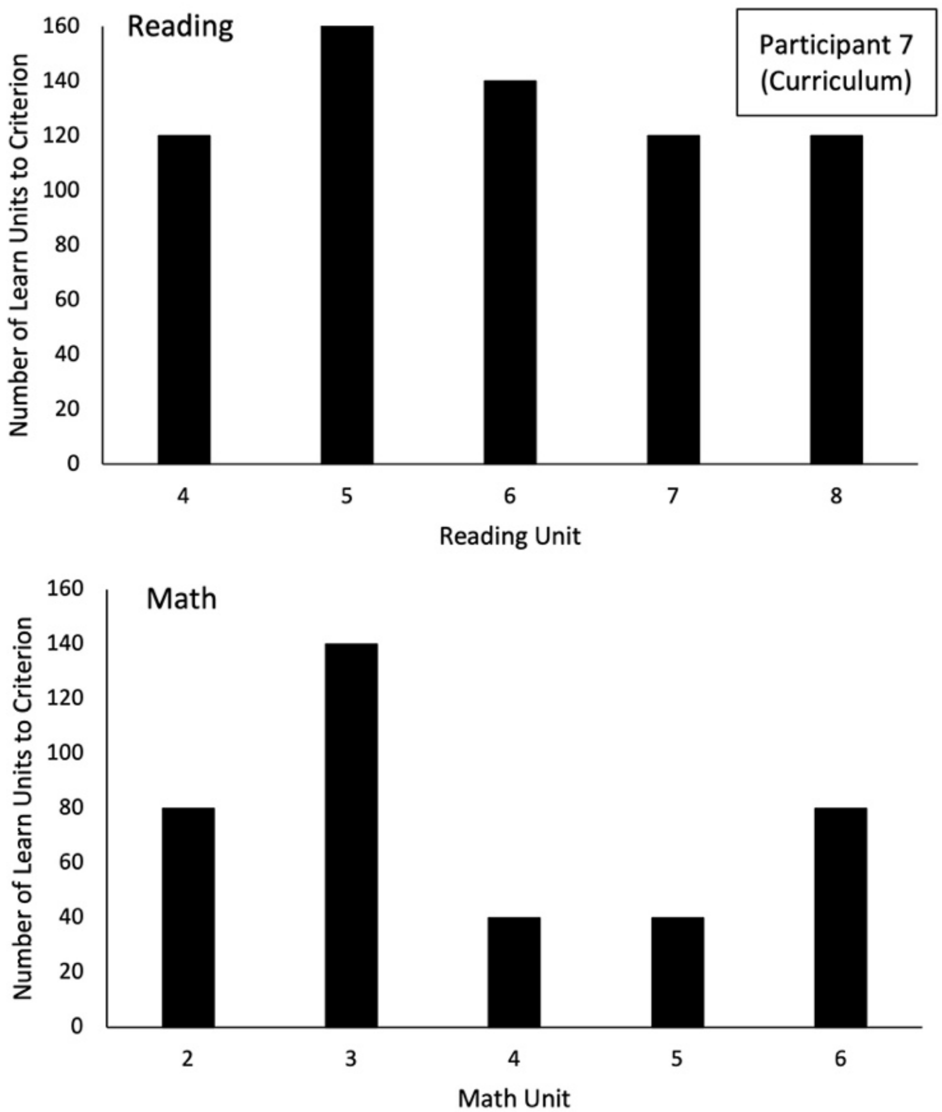


Figure 35. Number of LUC for Reading (top panel) and Math (bottom panel) pre- and post-demonstration of BiN for Participant 7.

Unconsequated Post Instruction Test

Participant 7 (see Figure 36) had a mean of 89.4% (range 83%-100%) accuracy in math post-unit tests, while the mean accuracy for reading post-tests was 86% (range 70%-100%) during the intervention.

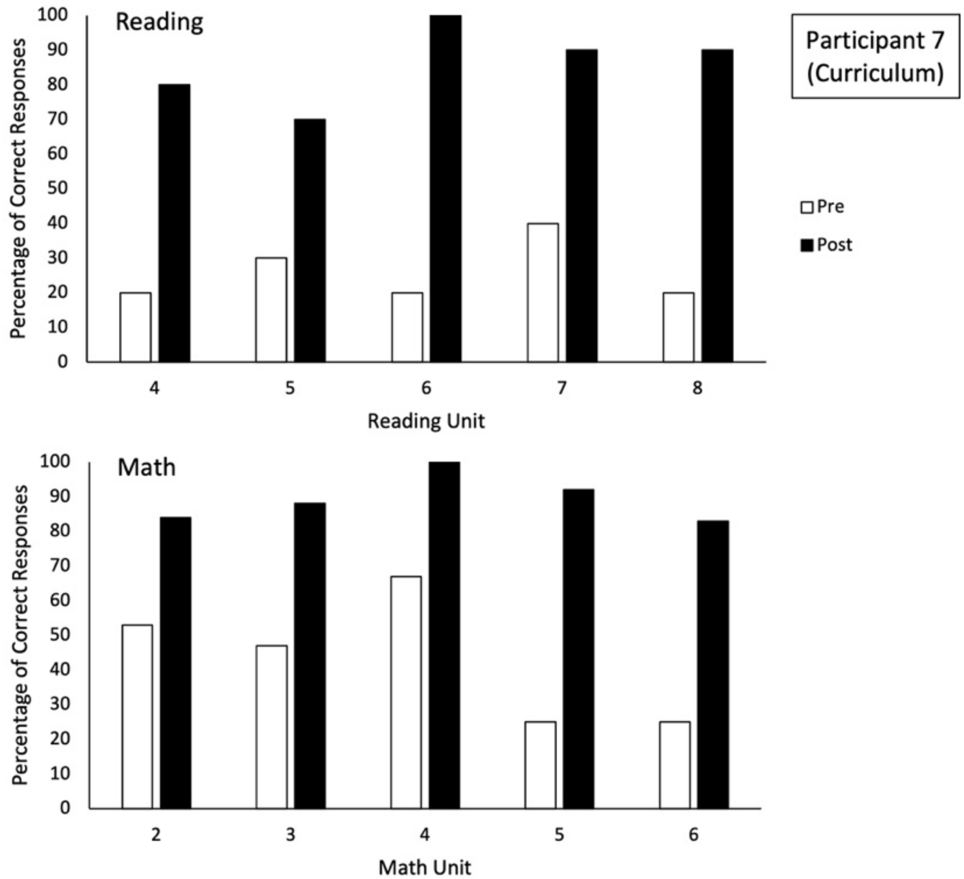


Figure 36. Unconsequated pre and post reading (top panel) and math (bottom panel) unit tests for Participant 5. White bars represent correct responses in pre-instruction unit tests. Black bars represent correct responses in the post-instruction unit tests.

Intervention

In Dyad 4 (see Figure 37), Participant 7 received a total of five intervention phases, consisting of 1020 academic learn units. Participant 8 received a total of two intervention phases, consisting of 520 naming experiences across 13 RNNE sessions. Neither participant demonstrating BiN in post-intervention probes with novel stimuli. Table 7 displays the number of academic learn units and RNNE session each participant received throughout the experiment.

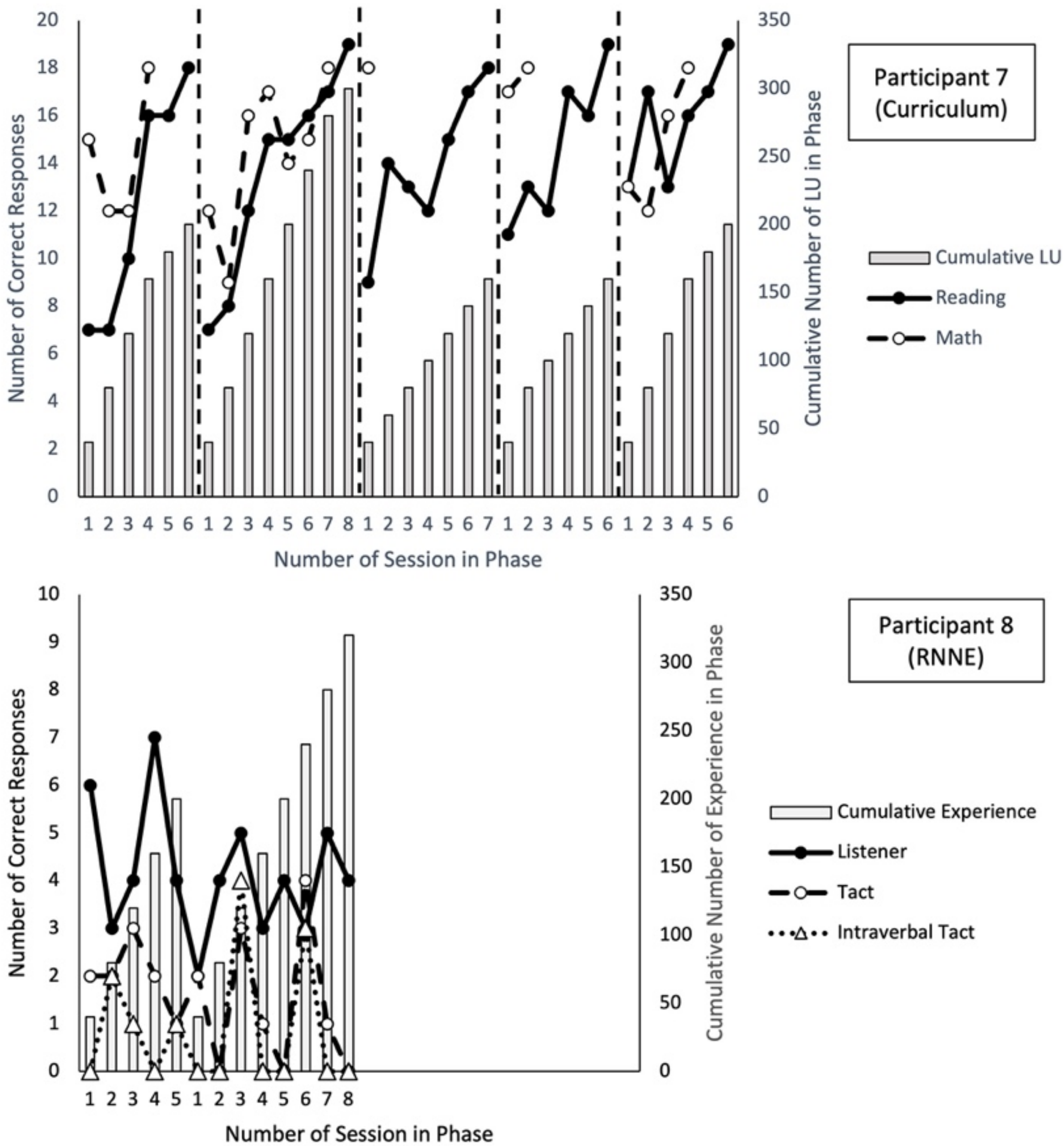


Figure 37. Intervention data for participants in Dyad 4. Participant 6's curriculum-based (top panel) and Participant 7's RNNE (bottom panel) intervention.

Discussion

Acquisition of BiN and Student Learning

In this experiment, I implemented a curriculum-based intervention and the RNNE intervention to test their effects on increments of BiN across two levels of complexity in preschool children. The results showed that the curriculum-based intervention condition was more effective than RNNE in inducing BiN when the participants were matched in dyads based on their chronological age and preexisting repertoires.

Following the curriculum-based intervention, Participants 1 and 3 demonstrated BiN for both familiar and unfamiliar picture-word relations level of complexity. Participant 5 demonstrated BiN for familiar picture-word relations level of complexity. Participant 7 continued to demonstrate UniN but did not demonstrate BiN after five intervention phases.

Participants 2, 4, 6, and 8 were assigned to the RNNE condition. Participant 4 demonstrated BiN for familiar picture-word relations level of complexity after three phases of RNNE, in which the number of picture-word relations experiences across sets were matched with the number of learn units that Participant 3, in the same dyad as Participant 4, received in the same phase. Participants 2 showed an increase in correct responses following each phase of RNNE but did not demonstrate the criterion level for BiN (i.e., 80% or higher accuracy). Participant 6 did not demonstrate BiN for any levels of complexity while their counterpart participants in the same dyad demonstrated BiN following the curriculum-based intervention. Participant 8 could not complete the study due to interfering behaviors and a descending trend in the number of correct listener responses.

Across participants who demonstrated BiN following the intervention, there were no significant differences in LUC across reading and math objectives regardless of the method of intervention (i.e., curriculum-based or RNNE). Additionally, the participants who met criterion for BiN using the curriculum-based intervention showed a decrease in LUC for math, but not a significant difference in LUC for reading.

All participants who received unconsequated pre- and post-unit tests following the mastery of each unit in the curriculum demonstrated mastery criterion (i.e., 80% or higher accuracy) in the post-unit tests. There was not a significant difference in post-unit performance between the participants who received the curriculum-based intervention or the RNNE to acquire BiN. The increase and demonstration mastery in post-unit tests show the effectiveness of curriculum in teaching the target academic objectives. However, additional analyses and data are needed to evaluate the effects of BiN on students' performance in unconsequated academic post-instruction tests.

The RNNE intervention is a measure of children's ability to learn through exposure. The RNNE emulates children's typical daily experience of exposure to language in a classroom. In RNNE, one experiences the picture and word relations, without consequences, then is later tested on the emergence of untaught picture-word relations using the same stimuli as the experience. Similarly, in a classroom, students experience the instruction materials and are expected to learn from teacher's lectures or models without consequences, as in the experience component in the RNNE. Some students will learn through teacher models alone, however, many students will not. Likewise, some children will acquire BiN through RNNE alone, but if they do not demonstrate BiN after multiple RNNE sessions (i.e., Participants 2 and 6 in Experient II), they require additional intervention.

Validity of Instruction across Environments: In-Home versus In-Class

Due to the COVID-19 pandemic, the setting of the experiment could not be controlled. That is, when the participants' school was closed due to COVID restrictions or the participant was in quarantine, the sessions of the experiment were conducted while the participant was in his or her home. While the school was open, the sessions were conducted in the participants' classrooms. Regardless of the participant's physical location, all probe and intervention sessions were conducted through the cyberspace. The participant and the researcher only interacted via online platforms (e.g., Google meets, Peardeck, GoGuardian).

To assess the possible association between the participants' physical environment and the session of the curriculum-based instruction, I conducted a chi-square test (see Table 6). According to the chi-square test, there was not a significant association between student's environment (i.e., in-home or in-class) and the content area of instruction (i.e., reading or math), X^2 (1, N=119) = .013, p=.908. This suggests that the participants' physical environment was not associated with the instructional content area that the participants were taught during the intervention.

Table 6. *Frequencies and chi-square results for reading and math instruction conducted in-person and virtual (N=119)*

Environment	Reading		Math		$\chi^2(2)$	p
	n	%	n	%		
In-person	31	57.41	23	42.60	.013	.908
Virtual	38	58.46	27	41.54		

Table 7. *Number of academic learn units and RNNE sessions across participants in Experiment II.*

Participant	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6

Dyad 1	1	R	80	R	80	R	20						
		M	40	M	60	M	20						
		T	120	T	140	T	40						
	2	S	3	S	4	S	1						
		NE	120	NE	160	NE	20						
Dyad 2	3	R	60	R	80	R	40						
		M	80	M	80	M	20						
		T	140	T	160	T	60						
	4	S	4	S	4	S	2						
		NE	160	NE	160	NE	80						
Dyad 3	5	R	120	R	60	R	100	R	60	R	20	R	60
		M	80	M	60	M	60	M	60	M	60	M	40
		T	200	T	120	T	160	T	120	T	80	T	100
	6	S	5	S	3	S	4	S	3	S	2	S	3
		NE	200	NE	120	NE	160	NE	120	NE	80	NE	120
Dyad 4	7	R	120	R	160	R	140	R	120	R	120		
		M	80	M	140	M	20	M	40	M	80		
		T	200	T	300	T	160	T	160	T	200		
	8	S	5	S	8								
		NE	200	NE	320								

Note. R=number of learn units to meet criterion for reading unit; M=number of learn units to meet criterion for math unit; T=total number of learn units across reading and math in phase; S=number of RNNE sessions; NE=number of novel naming experiences. Grey boxes indicate phases without intervention sessions.

CHAPTER IV

GENERAL DISCUSSION

In two experiments, I tested 1) the effects of a curriculum-based intervention on inducing BiN, 2) the differences between the curriculum-based intervention and the RNNE intervention on inducing BiN, and 3) the effects of the acquisition of BiN on students' academic performances.

In previous studies, researchers implemented MEI (Fiorile & Greer, 2007; Greer et al., 2007), ITI (Costa & Pelaez, 2014; Hotchkiss, 2019), repeated probe (Kleinert, 2018; Lo, 2016), and stimulus-stimulus pairing (Longano, 2008). The current study adds to the existing literature of interventions to induce BiN for picture-word relations in young children. Unlike previous studies, the intervention method of the current study simultaneously targeted inducing BiN and acquiring academic objectives.

In Experiment I, I implemented an academic curriculum, CABAS STEM Math and CABAS Reading, to test its effects on preschool students' increments of degree for BiN for familiar picture-word relations. The curriculum was differentially designed for students of varying degrees of BiN. In Experiment I, I used the UniN track of the curriculum because the participants demonstrated the presence UniN in their repertoires. The UniN track of the curriculum replicates intensive tact instruction (ITI), a pre-established intervention shown to induce BiN. Additionally, the UniN track is designed for learners who can learn as a speaker and derive untaught listener responses. The results of the experiment demonstrated that the curriculum-based intervention is effective in inducing BiN for familiar picture-word relations for students with UniN in their repertoires.

In Experiment II, I sought to compare the effects of the curriculum-based intervention and the RNNE intervention on participants' level of BiN across two levels of complexities. Additionally, I sought to test any different effects on participants' rate of learning and responses to unconsequated post-academic unit tests based on the method of acquisition of BiN. The participants were matched into dyads and randomly assigned a condition of the curriculum-based or the RNNE. All parts of the Experiment II were conducted in the cyberspace, with technology-mediation. The results demonstrated that the curriculum-based intervention was more effective than the RNNE in inducing BiN in the participants. The differential effects of the curriculum-based intervention and the RNNE on students' learning is inconclusive.

Major Findings

Effects of a Curriculum-based Intervention on Bidirectional Naming

Overall, the curriculum-based intervention was effective in inducing BiN for familiar and unfamiliar picture-word relations. In Experiment I, three out of four participants acquired BiN for familiar picture-word relations level of complexity. Participant D, who did not meet the criterion level for BiN (i.e., 80% or higher accuracy across all response topographies) still demonstrated a high accuracy of 100% listener, 70% tact, and 80% intraverbal tact responses. The results of Experiment I suggested the curriculum-based intervention can induce BiN in students with UniN in their repertoires.

In Experiment II, three out of four participants under the curriculum-based intervention acquired BiN for familiar picture-word relations. However, only one out of four participants under the RNNE condition acquired BiN for familiar picture-word relations. Additionally, two out of four participants under the curriculum-based intervention acquired BiN for unfamiliar picture-word relations, while none of the participants under the RNNE condition acquired BiN for unfamiliar picture-word relations. The results suggest not only the effectiveness of the curriculum-based intervention on students' acquisition of BiN, but also suggest that the curriculum-based intervention may be more effective than the RNNE intervention for preschool students with UniN in their verbal behavior repertoires. Additionally, the participants assigned to the curriculum-based intervention not only acquired BiN for multiple levels of complexity, but also learned academic objectives throughout the process. The academic gains of participants under the curriculum-based condition are evident in the unconsequated pre- and post-intervention unit tests.

Limitations

Experiment I

In Experiment I, Participant A demonstrated an ascending trend in the pre-intervention probes. Though Participant A acquired BiN following the intervention, the participant may have demonstrated BiN without an intervention, but through additional probes with novel experiences (Friedman, 2020). Additionally, Experiment I had a critically low number of IOA sessions. Due to the onset of the COVID-19 pandemic, IOA collection for additional sessions was difficult to attain.

Experiment II

Experiment II is not without limitations. Participant 4 of Dyad 2 demonstrated an increasing trend in pre-intervention BiN probes to unfamiliar picture-word relations. An increase in correct responses during probes without interventions may suggest the participant did not require an intervention to acquire BiN. The participant may have acquired BiN without an intervention, but through maturation. Additionally, Participant 2 in Dyad 1 was unable to participate in LUC and unconsequated posttest components of the study because the participant had the target academic objectives in repertoires. Because Participant 2 received instruction using a different curriculum than Participant 1, the instructional data could not be compared or analyzed.

Additionally, Participant 8 prematurely exited the experiment due to a decrease in listener responses in post-intervention probes and interfering behaviors (see Figure 38). Participant 8 emitted non-compliant behaviors in the school which included, but not limited to, taking the face mask off, screaming, property damage, elopement. Within a four-hour school day, Participant 8 emitted a mean of 41 min (range 15 min-86 min) of non-compliant behavior across 27 school days. These behaviors significantly interfered with Participant 8's participation in the study. Therefore, it was determined for the participant to exit the study.

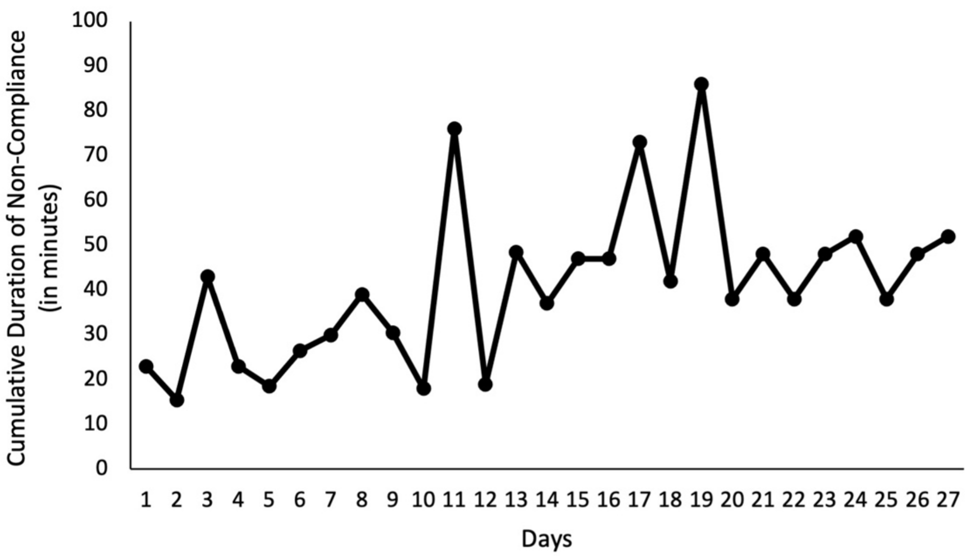


Figure 38. Daily cumulative duration of Participant 8's non-compliant behavior within a four-hour school day.

Student Learning Results

When a child acquires i-BiN, it "increases the child's learning capacity threefold" (Greer & Ross, 2008, p.151). There were four participants in the second experiment who acquired BiN through either the curriculum-based or the RNNE intervention. However, there were no significant difference in their rate of learning, measured using LUC, pre- and post-acquisition of BiN. There was a possible floor effect in the results of participants' LUC. Prior to the intervention and demonstration of the presence of BiN, the four participants already demonstrated a fast rate of learning based on their preexisting repertoires.

For example, Participant 3 had a mean LUC of 60 (range 40-80) in reading prior to acquiring BiN, while he demonstrated a mean LUC of 66.7 (range 60-80) post-acquisition of BiN. During the instruction, there are 20 opportunities to respond across all units and both curricula. Therefore, 60 LUC indicates that the participant only needed three instruction sessions to master the target objectives in the unit. In the classroom the participants were selected from, the mean LUC across 15 students and all instruction programs was 247.1 (range 67-518). All participants' pre-intervention LUC was significantly lower than the class-wide mean. This suggests a possible floor effect across the participants' LUC as the participants already demonstrate a fast rate of learning (i.e., low number of LUC).

Additionally, I used the decision tree protocol (Greer, 2002) to make instructional decisions during participants' academic instruction sessions using the CABAS curricula. The decision tree protocol instruction analyses are based on a 20-learn unit instruction session. Therefore, some of participants' instruction sessions consisted of previously mastered operants. For example, if Participant 3 had mastered emitting the target letter sounds under the intraverbal antecedent but had not mastered textually responding to target words in the unit, the participant repeated previously mastered letter sound emission operant in the next instructional session to complete the 20-learn unit program. If the decision analyses were conducted on an operant basis, the number of LUC across all participants would be lower as the participants would not have repeated previously mastered operants within the same unit.

Educational Implications

Technology-mediated Intervention

According to a survey conducted by the United States Census Bureau, almost 93% of households with school-age children reported engagement in some form of remote learning via online platforms and resources (United States Census Bureau, 2021) during the COVID-19 pandemic. Even after over a year into the pandemic, more than 70% of the elementary schools across the United States are still not recommended for “full in-person learning” according to the Center for Disease Control guidelines (CDC, 2021), the role of technology in elementary and early education may continue for an extended period of time. Some argue that remote learning will be a part of students’ regular education even after the pandemic is over.

In Experiment II, all parts of the experiment were conducted via technology mediated platforms. Despite participants’ young age (i.e., 4- to 5-year-olds at the end of the study), the participants were able to navigate and participate in experimental sessions without researcher or others’ help. Of course, all participants had necessary prerequisite skills to obtain their Chromebooks, turn the Chromebook on, and log in using a QR code. Once these skills were acquired, participants needed minor help to participate in instruction sessions. This suggests that the use of technology may expand further in early childhood education, even after the pandemic. Therefore, it is significant that the participants in Experiment II not only learned academic content, but also acquired a critical verbal behavior development cusp when intervention was delivered using technology.

Designing Instruction

Experiment I result suggested students can learn academic content while simultaneously acquiring a verbal behavior development cusp when the instruction was designed to replicate existing protocols to induce BiN. Experiment II results showed that participants acquired BiN at a faster rate, compared to their matched peer, when the participants received the curriculum-based intervention. The participants who received the curriculum-based intervention not only acquired BiN, a critical verbal behavior development cusp for accelerated language acquisition, but also learned academic content.

Language acquisition is critical to students' learning (Hart & Risley, 1995) and is a strong predictor of later academic success (Duncan et al., 2007). When a child demonstrates BiN, the child can learn language at an accelerated rate as they learn through experiences without needing a direct consequence (Hranchuck et al., 2019). As demonstrated in the current study, when the instruction was designed to induce this critical cusp, the participants learned academics and acquired BiN. This suggests that other verbal behavior develop cusps may be induced with instructional design alone, without the need of explicit protocols.

Long-Term Effects Curriculum-Based Intervention for Verbal Behavior Cusp

As discovered by Temple and Reynolds (2007), receiving a quality early childhood education is critical in long-term academic success of children and cost-effective. The students who received a quality early childhood education had lower rates of special education services in later grades. Another predictor of later academic success is language acquisition and development in early ages (Duncan et al., 2007). According to the VBDT (Greer & Ross, 2008), i-BiN is a critical verbal behavior development cusp that allows one to learn language incidentally. That is, if a child has i-BiN in repertoires, then the child's language development and acquisition will increase, which will positively impact the child's later academic success. Therefore, it is clear that academic success in later life can be structured from early schooling experiences, such as preschool and pre-kindergarten.

In the experiments I conducted, the students acquired i-BiN while receiving an academic curriculum-based intervention. This indicates that the participants acquired the verbal behavior development cusp that allow incidental language acquisition, without direct instruction or intervention. In addition to the language development, the participants also acquired academic objectives (i.e., reading and math) through the intervention. All participants were pre-kindergarten students. Conclusively, the participants not only received early childhood education along with academic objectives, but also acquired the capability to expand their language development. By implementing a curriculum-based intervention, the participants' outcome was maximized to set up these participants for success in later academic achievements.

Future Research

Multiple Levels of Complexity

In the current study, the participants demonstrated UniN for familiar picture-word relations level of complexity. Following the intervention, participants acquired UniN for familiar picture-word relations alone, or both familiar and unfamiliar picture-word relations levels of complexity. These are just two levels of complexity in BiN. Some other levels of complexity are BiN for action-word relations (Cahill & Greer, 2014) and BiN by exclusion (Greer & Du, 2015).

Unidirectional Naming for Picture-Word Relations

The NiN track of CABAS STEM Math and CABAS Reading curricula is designed to teach academic content while inducing BiN for students not demonstrating at least 80% accuracy in listener responses following a novel experience. The NiN track was designed to rotate listener and speaker responses, which emulates the response topographies of MEI (Fiorile & Greer, 2007) to induce BiN. I conducted a pilot study across two preschool students (see Figure 39) who demonstrated NiN prior to the intervention. Student G demonstrated UniN level of BiN for familiar picture-word relations after one intervention phase of NiN track CABAS Reading and CABAS STEM Math instruction. Student H demonstrated the presence of UniN after one intervention phase of intervention as well. A future research should expand to test the effects of the NiN track of the curriculum on the acquisition of BiN for students who previously demonstrated NiN.

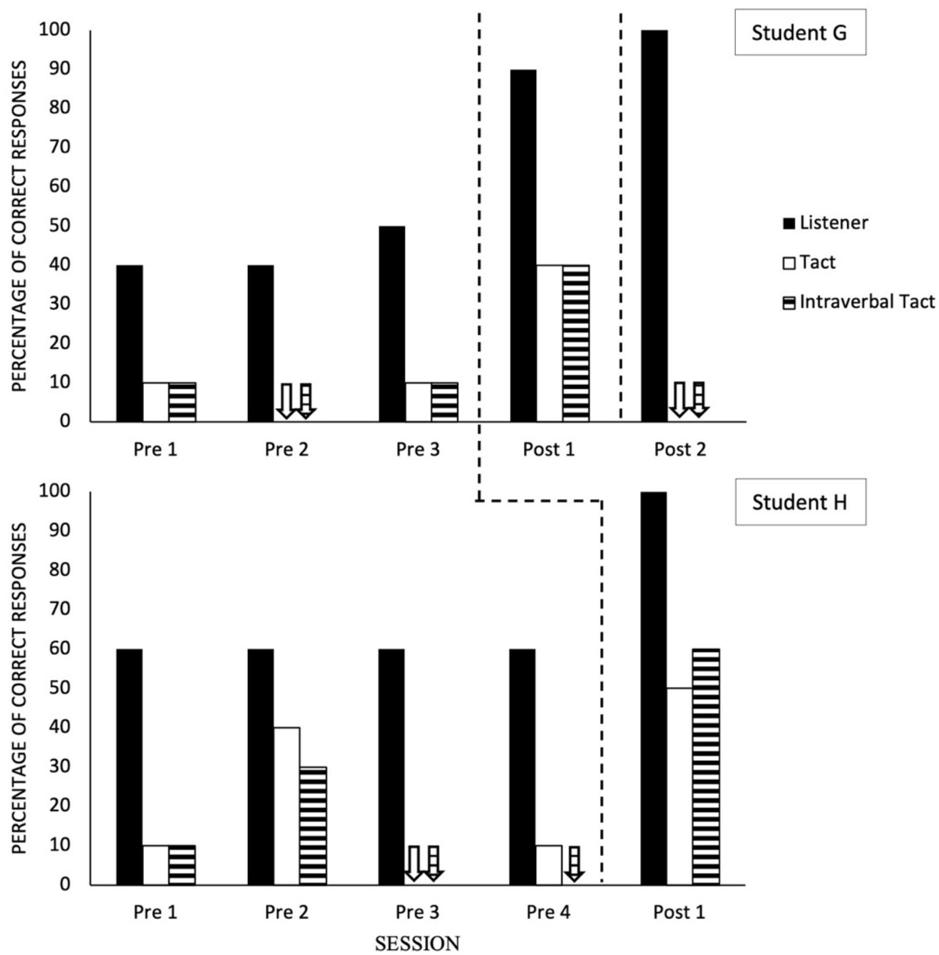


Figure 39. Pre- and post-intervention BiN data for familiar picture-word relations across two preschool students who demonstrated NiN prior to the intervention using the NiN track of the CABAS Reading and STEM Math curriculum.

Action-Word Relations

Through specific instructional design, it may be possible to induce BiN for action-word relations level of complexity. Prior research (Cahill & Greer, 2014) showed that MEI was effective in inducing BiN for action-word relations for children who demonstrated UniN prior to the intervention. The findings suggested specific instruction history of a child may affect the demonstration of BiN for action-word relations as the child selects out which component of the presented experience to observe. Additionally, the researchers found that the children emitted a higher accuracy when the word and object relations were presented without action during the novel experience. This suggests that the action may have interfered with the establishment of stimulus control for the object-word relations. We may apply these findings to instructional design to: 1) induce BiN for action-word relations level of complexity and 2) establish a repertoires that allows for a child to learn language incidentally without the interference of actions or other variables in the environment.

Exclusion

Vincent-Smith and colleagues (1974) found that young children learn names of objects at a faster rate when taught using the exclusion procedure. Greer and Du (2015) found that children can acquire novel object-word relations through exclusion, or a process of elimination, when presented with previously known stimuli. We can apply this principle to instructional design in two ways. First, for students who do not demonstrate BiN by exclusion, we can implement the exclusionary training (Greer & Du, 2015) in the instructional sequence to induce this cusp. For those who demonstrate BiN by exclusion, we can accelerate their learning by teaching certain objectives and presenting opportunities for the students to derive untaught responses through exclusion. Then a delayed posttest can be conducted to ensure the student acquired the derived untaught response in his repertoires.

Longitudinal Effects

Based on the literature, we can conclude that incidental language acquisition is a critical predictor in later academic success (Dodge et al., 2007). Most participants in the study acquired BiN for picture-word relations, which allows one to acquire language incidentally. Therefore, to test the long-term effects of demonstration of BiN, following these participants throughout their school years to assess the effects of acquisition of BiN in preschool years will be critical. Additionally, another study can compare the possible differences of long-term effects of acquisition of BiN based on different intervention methods to induce BiN will help identify the best method of intervention to induce BiN to students who do not demonstrate BiN.

Conclusion

In two experiments, I sought to test the effects of a curriculum-based intervention on preschool students' demonstration of BiN. The results of the study suggest that a curriculum with an embedded intervention to induce BiN in its instructional design can induce BiN for picture-word relations. The findings add to the current literature of interventions that effectively induce BiN to children who do not demonstrate this cusp. Additionally, the results demonstrated that it is possible for the students to simultaneously acquire BiN, a verbal behavior developmental cusp that is critical for language acquisition, and master academic objectives. Given the limited time the children have in their critical early childhood years, it is imperative that we target as many repertoires as possible to set the children up for success in the rest of their lives. As shown in the study, manipulating instructional design can increase the efficiency of instruction by both teaching academic objectives while inducing verbal behavior development cusps. To better serve the children, educators should consider the importance of instructional design to maximize the effects of instruction.

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